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ENTROPY AND TEMPERATURE-ENTROPY DIAGRAMS.

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[Paper presented at Annual Meeting.]

In the science of thermodynamics as at present developed we are concerned with the measure and mutual relation of the following properties and quantities connected with the working substance: Pressure, Volume, Temperature, Work, Energy, Heat, Entropy.

Of these the first three have certain direct relations to our natural senses, and their conceptions are correspondingly simple. Energy and work are familiar mechanical quantities, mutually convertible the one with the other, while by the first law of thermodynamics heat is but a form of energy, and is hence susceptible of measure either by means of a heat unit or by means of a mechanical unit expressed in terms of energy or work. The units being defined and their relations experimentally determined, heat and its measure become directly related to the familiar

conceptions and processes of physics and mechanics. With the definition and measurement of these six properties or quantities we suppose the reader already familiar.

Turning now to entropy and its measure, we first note that there is no natural sense corresponding to this quantity or conception, nor does its presence in greater or less degree give rise to any simple phenomenon which may be made the basis of a quantitative estimate of its value. It is, perhaps, simpler not to attempt to conceive of entropy as a *property* of a substance, but rather as a *relation* between or *function* of the fundamental properties p, v and T (pressure, volume and temperature), which relation or function remains constant during changes which involve no transfer of heat either to or from the working substance. The adiabatic nature of the change is therefore a defining condition, and entropy may be thus viewed as a relation between or function of p, v and T, which remains constant throughout such changes.

We may illustrate and enforce these points by the aid of a geometrical representation. Let us conceive of a substance in any condition defined by definite values of p, v and T. If for all simultaneous values of p and v, laid off as rectangular coördinates on a horizontal plane, the corresponding values of T are laid off vertically, the extremities of such ordinates will determine a surface which will show graphically all possible simultaneous values of p, v and T for the given substance. Such a surface will serve, therefore, to give a complete and continuous history of all changes in the substance as determined by continuous changes in the properties p, v and T. Now all manner of lines may be drawn upon the surface, and any given line will represent a possible path of reversible change for the substance in question; or, conversely, if we subject the substance to any series of small, continuous or reversible changes of condition, the complete history of such a change may be represented graphically by a line or path traced on the surface in accordance with the successive changes in the values of p, v and T. If now from any point we draw on the surface a very short line in any given direction, such line will correspond to a small change of the body

starting from the condition represented by the initial point. In general, as a necessary accompaniment of such change, heat must be either added or subtracted. It is obvious, however, that there will in general be an intermediate direction for which heat will be neither absorbed nor rejected, and by adding continuous steps fulfilling this condition, we may trace out a path along the surface for the changes corresponding to which no transfer of heat will be required. Such paths may be traced over the entire surface, and the latter may, in fact, be considered as formed by an indefinite number of them located at an indefinitely small distance apart. These paths are the well known adiabatic or isentropic curves, and any one of the series is the representation of a certain definite relation between its coördinates, and therefore between the values of p, v and T, to which it corresponds. It follows that the equation resulting from equating the function expressing entropy to the constant value which it would have for such a curve would be one of the many forms into which the equation to such a curve might be thrown. In other words, there might be an indefinite number of functions constant for such a curve, and any of them may be taken as furnishing its equation, some one of them being the particular function expressing the value of entropy in the units commonly employed. The definition of entropy as a function of p, v and T constant for an adiabatic change, therefore, simply places it in an indefinite family of such functions, all derivable the one from the other, and all fulfilling the same fundamental conditions.

To complete our ideas by defining the particular function whose value is to remain constant during adiabatic change, we must approach the subject in a somewhat different manner.

It is well known that the value of a definite integral depends simply on the initial and final values of the independent variable, and that it is independent of the intermediate series of values passed through. Conversely, it follows that if the properties of a body or quantities related to such properties are determined solely by the conditions of such body and are independent of intermediate steps or stages, then all change in such properties or quantities, or in the value of any function of such properties or

quantities, may be expressed as a definite integral, and the element of such an integral is called a complete differential. As a simple illustration of a quantity capable of being expressed as a definite integral, we may take for a given time the amount of increase of the water in a cask as determined by the difference between the quantities in the cask at the beginning and end of the interval taken. Such amount will be completely determined by the difference of these two quantities, and will be independent of the rate of flow into the cask, whether slow or fast, uniform or variable, or even whether there is or is not a leak for a part or whole of of the same time.

If, however, a change in the properties of a substance or in the value of a quantity depending on such properties depends on the particular series of intermediate changes, or, in other words, on the path followed, then the amount of such a change cannot be expressed as a definite integral, and its element is not a complete differential. If, moreover, the value of the change in any portion of a quantity or function be thus dependent on the path, then it follows that the value of the change as a whole cannot be expressed as a definite integral, and that its element is not a complete differential.

Now let us examine for a given substance the heat involved in a given change of condition. This is divided into the three well known parts: (1) That involved in change of temperature or in change of internal kinetic energy; (2) That involved in internal or molecular work not involving change of temperature or in change of internal potential energy; (3) That involved in the external work either received or performed. The first two of these reckoned from an assumed origin constitute the so-called energy of the substance and are resident, so to speak, in the body itself. The analogy of water added to and subtracted from the cask is here applicable, and the quantity of heat or energy involved in such changes depends solely on the initial and final conditions and is independent of the intermediate stages. Such parts of the total heat may, therefore, be expressed as a definite integral, and the corresponding element is a complete differential.

When we turn to the external work, however, we find a different condition. The amount of work is expressed by $\int p\,dv$, and this will depend not only on the initial and final values of p and v, but on the intermediate values of p as well. The heat involved is dependent, therefore, on the path followed, and the element $p\,dv$ is therefore not a complete differential. It follows that the element dH of the heat as a whole is likewise not a complete differential, nor can the heat as a whole be represented by a definite integral summed between the limiting conditions for the change in question. It is, however, very desirable for the investigations of many problems in thermodynamics that the heat involved in any change in the conditions of a substance, even if not capable of expression directly in terms of a definite integral, should, if possible, be related to an integral of this character, and thus brought into direct relation with a quantity or function depending solely on the initial and final conditions of the change. This operation is most conveniently effected on the element of the heat, thus transforming an incomplete into a complete differential. Such devices are very common in the treatment of differential equations, and the factor which can effect such a change is known as an *integrating factor*. In the present case let us represent such a factor by μ. Then, according to definition, $\mu\,dH$ is a complete differential. The differential thus transformed we may represent by $d\varphi$, where φ is the function whose values will depend solely on the condition of the body, and for which the differences in value may therefore be expressed as a definite integral. We have, therefore, as a fundamental equation:

$$d\varphi = \mu\,dH.$$

Now, without entering in detail into all the steps of the process, it will be sufficient for present purposes to state that the μ thus defined is the reciprocal of the absolute temperature, and that such is the case because absolute temperature is so defined. It is true that absolute temperature is not usually defined in exactly this way, but it is none the less true that, thermodynamically, the absolute

temperature is to be considered simply as the reciprocal of an integrating factor. From another point of view, we may consider that the integrating factor is defined as μ in the equation above, that it is taken as independent of the substance, and that its value and relations to the other properties are found, and that then the reciprocals of the series of values thus found for different conditions of the body are taken as determining an absolute thermometric scale. The thermodynamic scale of absolute temperature has really no other logical foundation than this. Representing, therefore, the reciprocal of μ by T we have:

$$d\varphi = \frac{dH}{T} \quad \text{or} \quad dH = Td\varphi. \quad . \quad . \quad . \quad . \quad (1)$$

Hence $$\varphi = \int \frac{dH}{T} \text{ and } H = \int Td\varphi. \quad . \quad . \quad . \quad (2)$$

To the function φ thus defined by (1) and (2), the name entropy is given. That it is constant for an adiabatic change follows from (1), while the same equation, or (2), following direct from (1) serves to particularize the function φ among the indefinite number which might fulfil the condition of constancy for adiabatic change.

We have thus completed the definition of the function φ, the measure of the entropy of the substance. Let us consider it simply as a function of p, v and T, fulfilling the conditions expressed in (1) and (2).*

A study of the value of φ, as given in (1), will serve to throw some light upon its physical nature. It thus appears that entropy will increase with the heat added, and that it makes no difference whether such heat is stored in the body as internal energy or is transformed into external work. *Vice versa* it will decrease with

* It may be noted in passing that there may be an indefinite number of integrating factors related to μ or $\frac{1}{T}$, but differing from it and from each other, and each would serve to establish a different system of entropy. For a discussion of these points, reference may be made to an article by the author published in the "Physical Review," Vol. IV, page 343.

heat subtracted, and it makes no difference whether such heat comes from the store of internal energy or from transformed external work. Entropy does not, however, increase and decrease with the exact rate of the added or subtracted heat. Other things being equal, the rate of change of φ will vary inversely with T, so that a given amount of heat added or subtracted at a low temperature is more effective in changing the entropy than the same amount added or subtracted at high temperature. In general, a large value of the entropy means that, reckoning from some arbitrarily assumed initial point, a large amount of heat has been received, the larger the amount the higher the temperature of reception; or a small value implies a small amount of heat received, the less, the lower the temperature of reception, and *vice versa* in each case.

As an illustration of the relation of entropy to heat, the following mechanical analogy, though only partly applicable, may be made use of. Imagine a vertical hoist carrying a large, shallow reservoir for water. This reservoir is supposed to be so large and so shallow that, no matter how much water it may contain, the entire amount may be considered as practically at the same level or altitude. Let us furthermore suppose that we can add or subtract water at any altitude from any convenient base; let us go through a series of operations involving in the most general case the raising of successive small amounts of liquid, and their addition at continually varying levels of the reservoir, or the subtraction of like small amounts at continually varying levels, and their deposition at the base. Taking the amount of liquid handled at any one operation as indefinitely small, we may represent its weight by dW and the corresponding altitude by h. The work involved in the operation will be, therefore, $h\,dW$. It must be particularly noted that only the work involved in raising the liquid before it is placed in the reservoir, or in lowering it after its removal, is to be here considered. The mechanical work involved in raising or lowering the reservoir or the water in it as a whole, is not here under consideration. Calling work done in raising the liquid $+$, and in lowering it $-$, the net work involved in the series of operations will be:—

$$Q = \int h\, dW, \quad \ldots\ldots\ldots \quad (3)$$

or $$dQ = h\, dW, \quad \ldots\ldots\ldots \quad (4)$$

and $$dW = \frac{dQ}{h}, \quad \ldots\ldots\ldots \quad (5)$$

and $$W = \int \frac{dQ}{h}. \quad \ldots\ldots\ldots \quad (6)$$

The similarity in form between these equations and those deduced above for entropy is plain. Equation (6) is seen to give the net weight handled, and this is similar to the value of φ in (2), showing that this weight has the same relation to the mechanical problem that entropy has to the thermodynamic problem. For this reason entropy is sometimes called the *heat weight* of the system or substance. Furthermore, the altitude of the reservoir h corresponds to temperature T, while the work Q involved in raising or lowering the liquid in the mechanical system corresponds to the heat H involved in a change of the thermodynamic system. Again, if we suppose liquid to be added or subtracted at a constant altitude of reservoir, the operation will correspond to change of entropy at constant temperature. If we suppose the amount of liquid to remain the same and the reservoir to be raised or lowered, the operation will correspond to change of temperature at constant entropy. More generally, if liquid be added or subtracted and the altitude continuously increased or decreased at the same time, the operation will correspond to an increase or decrease of entropy with rising or falling temperature according to the mutual relation of the quantities involved.

T Φ DIAGRAMS.

In Fig. (1) let $O\Phi$ and OT be axes of entropy and temperature, and let AB denote the continuous T history of any change in a substance. Then for this change the heat required will be:

$$H = \int T\, d\varphi.$$

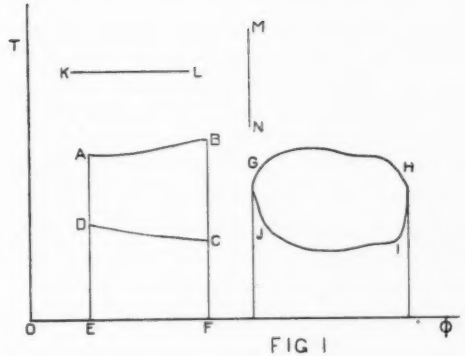


FIG 1

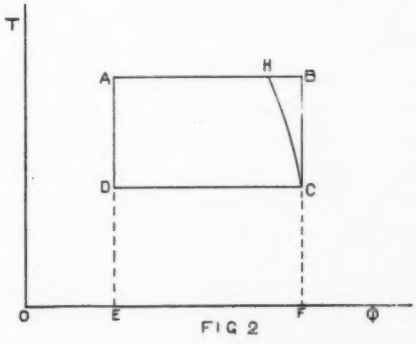


FIG 2

This is represented by the area $A\,B\,F\,E$. Hence, on this diagram the area between the axis of Φ and any line representing the $T\,\Phi$ history of a continuous or reversible change in the conditions of the substance represents the total heat involved in such change. This is exactly similar to the manner in which the like area for a diagram on axes of p and v represents the external work. It is this fundamental property which gives to temperature-entropy diagrams their peculiar suitability for the examination of certain thermodynamic questions.

(*a*) Let $G\,H\,I\,J$ denote any closed path representing the history of a cyclical series of changes in a substance; then, taking G as the initial and final point, it is obvious that since the body returns to its inital condition its energy must be the same. Hence the heat involved in the operation will be the exact equivalent of the external work. But the heat for any change, as we have seen, is represented by the area of the diagram between the path of the change and the axis of Φ. Hence for a cyclical operation the net heat involved will be represented by the net or closed area of the diagram. Hence for such an operation the closed area will represent the external work, the same as in the $p\,v$ diagram. Hence, if the history of a cyclical operation were represented on both sets of axes, $p\,v$, and $T\,\Phi$, the resultant diagrams, while differing widely in shape, will each represent, the one in heat units and the other in mechanical units, the external work involved.

(*b*) In a $T\,\Phi$ diagram the isothermals are lines parallel to the axis $O\,\Phi$, such as $K\,L$, for example, while the adiabatics are lines parallel to the axis $O\,T$, such as $M\,N$, for example. A combination of such lines so as to form a Carnot cycle will be therefore represented by a rectangle, as in Fig. 2. The substance increases in entropy at constant temperature from A to B, then decreases in temperature at constant entropy from B to C, then decreases in entropy at constant temperature from C to D, and then increases in temperature at constant entropy from D to A, thus traversing the cycle and doing external work represented by the area $A\,B\,C\,D$. Likewise $A\,B\,F\,E$ represents the heat absorbed during operation $A\,B$, and $D\,C\,F\,E$ that rejected during operation $C\,D$. Hence the diagram shows the partition of the total heat

into the two parts: $A\,B\,C\,D$ utilized and $D\,C\,F\,E$ rejected. The efficiency is therefore represented by the ratio $\frac{ABCD}{ABFE}$ or by $\frac{AD}{AE}$.

(*c*) It is obvious that any cyclical operation for which the closed area is the same as the above will represent a cycle of equal external work. This area will evidently remain constant for all figures derived from $A\,B\,C\,D$ by deformation parallel to $O\,\Phi$: that is, for all areas for which the horizontal intercepts between the two other sides are constant and equal to $A\,B$. Hence in Fig. 3 $A\,B\,C_1\,D_1$, $A\,B\,C_2\,D_2$, etc., represent a series of cycles between the same temperature limits for which the external work is the same. For the cycle $A\,B\,C_1\,D_1$ the heat absorbed is represented by $E_1\,D_1\,A\,B\,F$ and that rejected by $E_1\,D_1\,C_1\,B\,F$. For such a cycle it is evident that the portion $E_1\,D_1\,A\,E$ of the heat absorbed is equal to the portion $F_1\,C_1\,B\,F$ of that rejected. If, then, as the latter is rejected it could be transferred over, so as to supply the demand corresponding to the absorption of the former, the one would balance the other, and the heat actually required from an external source would be represented by $E\,A\,B\,F$, as in the Carnot cycle. The heat actually rejected would also be represented by $E_1\,D_1\,C_1\,F_1$, equal to $E\,D\,C\,F$, as in the Carnot cycle. Hence their difference, or the heat transformed into external work, is the same, as we have already seen. Such cycles are known as isodiabatic, and under the conditions assumed are evidently equal in efficiency to the Carnot cycle.

(*d*) We wish now to show that with a simple cycle, *i. e.*, one not involving heat transfers, as in the last case, any departure from the Carnot form involves a loss of efficiency. To this end let $J\,K\,L\,M$, Fig. (4), denote a departure from the adiabatic $B\,C$. Then the efficiency of the orginal or Carnot cycle will be $A\,B\,C\,D \div A\,B\,F\,E$, while for that of the new cycle we shall have to add to the numerator the area $J\,K\,L\,M$ and to the denominator the area $J\,K\,G\,F$. It is obvious that the ratio $J\,K\,L\,M \div J\,K\,G\,F$ is less than $A\,B\,C\,D \div A\,B\,F\,E$, and hence that the addition of the numerators and of the denominators will decrease the value of the final ratio, and hence the efficiency of the modified cycle will be less than that of the original. The same is evi-

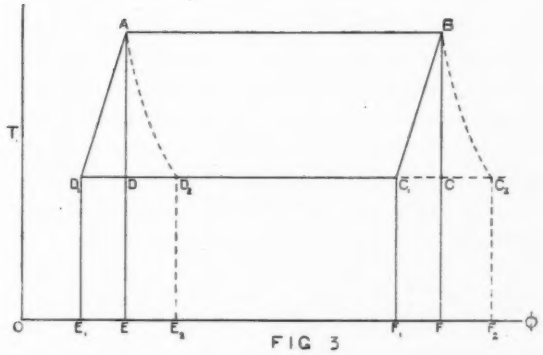


FIG 3

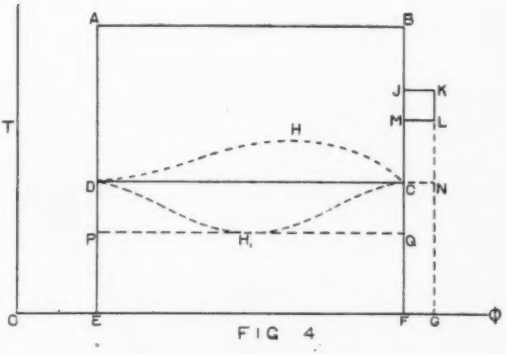


FIG 4

dently true for such a modification as $J\ K\ N\ C$, and similarly for any addition to the diagram beginning at a level lower than $A\ B$ or ending at a level higher than $D\ C$. Similarly for a departure from the isothermal, as shown by $D\ H\ C$, the efficiency is evidently decreased since the heat absorbed is the same and the work performed is less. On the other hand, for a departure such as $D\ H_1\ C$, the efficiency is increased relative to the original temperature limits, but relative to a Carnot cycle between the limiting temperature the cycle $A\ B\ C\ H_1\ D$ is evidently of less efficiency than that represented by $A\ B\ Q\ P$. In general, therefore, any departure from the Carnot cycle will result in a loss of efficiency relative to that for such a cycle between the limiting temperatures, and hence in this sense any and all departures from the Carnot cycle are detrimental to efficiency. Illustrations of these various cycles may be readily derived by appropriate manipulation of the mechanical analogy described above, the details of which may be readily supplied by the reader.

THE APPLICATION OF THE DIAGRAM TO MOIST STEAM.

We have first to develop certain fundamental equations and then to investigate their interpretation by means of $T\ \Phi$ diagrams. Let entropy be counted from any origin the temperature of which is represented by T_0. Then if T_1 is any other temperature we have:

$$\text{Horizontal co-ordinates} = \varphi = \int_{T_0}^{T_1} \frac{dH}{T}.$$

$$\text{Vertical co-ordinates} = T.$$

But if c is put to represent specific heat in general, we have:

$$dH = c\,dT,$$

hence
$$\varphi = \int_{T_0}^{T_1} c\,\frac{dT}{T},$$

and
$$\frac{d\varphi}{dT_1} = \frac{c}{T}\Big]_{T_1} = \frac{c}{T_1},$$

or in general
$$\frac{dT}{d\varphi} = \frac{T}{c}. \quad \ldots\ldots\ldots\ldots \quad (7)$$

Now any continuous change in the conditions of the substance will be represented by a continuous curve relative to these axes, and at any point on this curve the ratio $dT \div d\varphi$ is the tangent of the slope relative to the axis of Φ. The subtangent on the same axis is also equal to the ordinate $T \div \frac{dT}{d\varphi}$.

Hence from (7) we have:

$$\text{Subtangent} = T \div \frac{T}{c} = c = \text{specific heat.} \quad . \quad . \quad (8)$$

Therefore for any change corresponding to an element of a curve drawn on a $T\Phi$ diagram, the specific heat is represented by the subtangent on the axis of Φ. The inclination of the curve, and hence of the tangent, shows whether this value of c is positive or negative.

Now in the case of moist steam let:

x = quality of the steam or percentage which is vapor.
q = heat of liquid for one pound.
r = latent heat for one pound vapor.
λ = total heat for one pound mixed liquid and vapor.

Then $\lambda = q + xr$. . . . . (9)

Now, reckoning from the freezing point of water and taking all quantities as relating to one pound, we have:

$$\varphi = \int_{T_0}^{T_1} \frac{dH}{T} = \int_{T_0}^{T_1} \frac{d\lambda}{T} = \int_{T_0}^{T_1} \frac{dq}{T} + \frac{xr}{T_1} \quad . \quad . \quad . \quad (10)$$

For water alone, we have $x = o$ and

$$\varphi = \int_{T_0}^{T_1} \frac{dq}{T} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (11)$$

and for saturated vapor, where $x = 1$, we have:

$$\varphi = \int_{T_0}^{T_1} \frac{dq}{T} + \frac{r}{T_1} \quad . \quad . \quad . \quad . \quad . \quad . \quad (12)$$

We now wish to find the heat necessary to bring about a slight change in any or all of the conditions. To this end we

must find for such change the general value of $T\,d\,\Phi$. It is not sufficient to differentiate the value of λ, because this gives the difference in the total heat required to form from water at the freezing point the substance in the two conditions. This, however, is not the same thing as the heat required to transform one condition into the other.

We therefore consider all quantities in the general value of φ given in (10) as variable, and differentiating we have, omitting the subscript on T:

$$d\varphi = \frac{dq}{T} + \frac{x dr}{T} + \frac{r dx}{T} - \frac{x r dT}{T^2}. \quad . \quad . \quad . \quad . \quad (13)$$

Whence $$dH = T d\varphi = dq + x dr + r dx - x r \frac{dT}{T}. \quad . \quad . \quad (14)$$

or $$dH = dq + d(xr) - x r \frac{dT}{T}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (15)$$

If the specific heat of water is denoted c_1 by then $dq = c_1 dT$, and we readily transform (14) into:

$$dH = (1 - x) c_1 dt + r dx + x \left(c_1 + \frac{dr}{dT} - \frac{r}{T}\right) dT. \quad . \quad (16)$$

If in (16) we let $x = 1$, the value reduces to its last term and we have:

$$\frac{dH}{dT} = \left(c_1 + \frac{dr}{dT} - \frac{r}{T}\right). \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

This is the specific heat of saturated vapor, or, in other words, the specific heat for a change in which the quality remains constant at 1. For a change at some other constant quality, x_1, we have:

$$\frac{dH}{dT} = c_1 + x_1 \left(\frac{dr}{dT} - \frac{r}{T}\right). \quad . \quad . \quad . \quad . \quad (18)$$

Equation (16) shows the three partitions of heat, thus:

$(1 - x) c_1 dT$ goes to the water,

$r dx$ is latent heat,

$x \left(c_1 + \frac{dr}{dT} - \frac{r}{T}\right) dT$ goes to raise the temperature of the steam.

CONSTRUCTION OF THE DIAGRAM FOR WATER AND STEAM.

See Fig. 5.

The diagram for water and steam may now be constructed as follows. The origin for temperature is taken at the freezing point of water and the T axis is extended downward to the absolute O and upward as far as may be required. The origin of entropy is likewise taken at the freezing point of water and the axis is extended to the right as far as may be required. The curve $O\,A$ gives the relation between T and φ for liquid water plotted according to the scales, as shown. Similarly and relative to the same axes the curve $B\,C$ relates to saturated vapor. The horizontal intercepts between $O\,A$ and $B\,C$ are then divided into any convenient number of equal parts, as shown, and intermediate curves are drawn through the points of division. Then, by reference to (9), it is readily seen that each intermediate line thus drawn will give a $T\varphi$ curve for a constant quality of vapor, as indicated at the margins $A\,B$ or $O\,C$. Along the axis $O\,\Phi$ there are laid off two scales of equal parts, one for φ and rising from o to 2.2 for the point C, and the other for quality, and rising from o to 1.

This system of representation involves, therefore, the use of a curvilinear axis of ordinates for quality and a rectilinear axis of ordinates for entropy, so that for any point the quality is to be referred to the scales along $O\,\Phi$ or $A\,B$ by means of the curved lines of constant quality, while the entropy is to be referred to the scale along $O\,\Phi$ by means of straight lines parallel to $O\,T$.

On the left, $O\,D$ is laid off to represent the relation between p and T, p being laid off to the left on $O\,X$. Likewise $E\,F$ is laid off to represent the relation between Tp and volume u. $O\,G$ represents any value of T, $G\,H$ the corresponding value of p, and $J\,K$ the corresponding value of u.

In the diagram the principal lines are evidently as follows:

Adiabatics or isentropics are vertical.

Isothermals are horizontal.

* For several features of this diagram the author would acknowledge his indebtedness to the diagram proposed by Ancona in the "Vereines der Deutschen Ingenieure" of April 17, 1897.

FIG 5

Isopiestics, or curves of constant pressure, are horizontal between $O\,A$ and $B\,C$.

Isometrics, or curves of constant volume, are represented by $I\,Q$. They approach asymptotically to the lower limit curve $O\,A$.

Isenergics, or curves of constant energy, are represented by $B_1\,C_1$.

Referring to (8), it is evident that the subtangent for any point of the upper limit curve $B\,C$ will give the corresponding value of the specific heat of saturated steam as given in (17). Similarly for the other curves of constant quality, a subtangent will give the corresponding value of the specific heat, as shown by (18). It has been already mentioned that the criterion for the sign of these specific heats is furnished by the inclination of the tangent line or of the curves at the given point. Hence for variation at constant quality the sign of the specific heat will be indicated by the inclination of the curves lying between $O\,A$ and $B\,C$. It is thus seen that for $O\,A$ and those near it, or, in other words, for mixture in which water largely predominates, the specific heat for change at constant quality is (+), or increase of temperature is accompanied by the absorption of heat. On the other hand, for $B\,C$ and for curves near by, or, in other words, for mixtures in which vapor largely predominates, the specific heat for change at constant quality is (—), or increase of temperature is accompanied by the rejection of heat, and *vice versa*. For intermediate curves, as is seen, the tangent is (+) for some values of T and (—) for others showing a change in the sign of the specific heat, and therefore a o value at the point of change. At such a point change of temperature at constant quality is accompanied by no heat exchange, or, in other words, the change is adiabatic in character. The collection of points for which this condition is fulfilled is shown by $B_2\,C_2$, and has been called by Ancona* the *null curve*. Points on this curve may be obtained as follows: From (13) for constant quality we have:

$$\frac{d\varphi}{dT} = \frac{dq}{TdT} + \frac{xdr}{TdT} - \frac{xr}{T^2} \quad . \quad . \quad . \quad . \quad . \quad (19)$$

* "Vereines Deutscher Ingenieure," as above.

This is the tangent of the slope relative to the axis of T for curves of constant quality. At points on the null curve $\frac{d\varphi}{dT}=0$, and this gives for x the following value:

$$x=\frac{\frac{dq}{dT}}{\frac{r}{T}-\frac{dr}{dT}} \quad \ldots\ldots\ldots \quad (20)$$

From this equation, by the aid of tables giving the usual properties of steam, the values of x for all values of T may be found. The values of the differential coefficients may be determined with all needful accuracy by taking one-tenth the difference in the values for a 10 degree interval. Thus for 250 degrees the value of r for 245 degrees is subtracted from that for 255 degrees, the difference divided by 10 and the result taken as the value of $\frac{dr}{dT}$ for this temperature, and similarly for $\frac{dq}{dT}$.

From (19) it is evident that for a constant value of T the value of $\frac{d\varphi}{dT}$ will increase by equal increments for equal increments in the value of x. It follows that all tangents to the curves of constant quality at a constant value of T will meet at a common point or focus. This is illustrated by the lines meeting in V_2 tangent on the line JV_1. The usual partition of the heat involved in any change of condition has been already referred to in an earlier part of the paper. Repeating this, we have for the subdivision of the total heat:

(1) Heat involved in change of temperature.

(2) Heat involved in internal work, or the so-called inner latent heat.

(3) Heat corresponding to the external work.

(1)+(2) constitute the energy.

(2)+(3) constitute the entire latent heat.

This partition may be represented on the diagram as follows: For the condition denoted by the point P, the total heat is represented by $NOLPM$. The part (1) is represented by $NOLR$,

and, therefore, the area $R\ L\ P\ M$ will represent the sum of (2)+(3), the total latent heat. If now the external work expressed in heat units is divided by $L\ P$, we shall obtain a length $L\ S$. Laying this downward from L we have the external work represented by $L\ P\ U\ S$, and have the internal work by $R\ S\ U\ M$. Since at constant temperature both the internal and external works, and their sum, are proportional to the value of x, it follows that the length $L\ S$ will be independent of x, and hence the line $S\ V$ will serve as the dividing line for the internal and external work for all values of x at this particular value of T. The curve $W\ Z$ shows the locus of the lower ends of the lengths similar to $L\ S$, so that by drawing from any point on $O\ H$ a vertical to the line $W\ Z$, the partition of the corresponding total heat for any value of x may be readily represented in manner as described.

PARTITION AND EXCHANGE OF HEAT ENERGY AND WORK IN ANY GIVEN OPERATION.

In addition to showing the partition of the total heat corresponding to the formation of one pound of vapor in any condition as regards T and x, the diagram may be made to illustrate in a very interesting way the partition and exchange of heat, energy and work for any given change in condition. Thus in Fig. (7) let $P\ Q$ denote any given change, involving in this case increase of φ and decrease of T.

Let E denote the internal energy, kinetic and potential.

H denote heat.

W denote work.

Then, taking work done by the substance as (+), we shall have for any change in general:

$$H = E + W$$

or

$$W = H - E.$$

Now, let us take first the special case of adiabatic change represented by $P\ Q$ in Fig. (6). In this case no heat exchange is involved, and the decrease of energy will equal the work done. In the condition P the kinetic energy is represented by the area

$O\,A\,J\,E$ and the potential energy by $B\,C\,D\,J$. Hence the energy as a whole is represented by the area hatched upward and to the right. Similarly the energy in the condition Q is represented by the area $O\,A_1\,B_1\,C_1\,D\,E$ hatched upward and to the left. The decrease of energy, and hence the work done, is therefore represented by the singly hatched area $A_1\,A\,B\,C\,C_1\,B_1$. Remembering the preceding explanations, the partitions of the various quantities are readily seen to be as follows:

For the external work:

$A_1\,A\,G\,B$ done at the expense of kinetic energy in condition P.
$B\,C\,C_1\,G$ done at the expense of potential energy in condition P.

For the energy in the condition P:

$O\,A_1\,K\,E$ (kinetic) remains unchanged.
$G\,C_1\,D\,J$ (potential remains unchanged.
$B_1\,G\,K\,J$ transferred from kinetic to potential.
$A_1\,A\,G\,B$, (kinetic) does external work.
$B\,C\,C_1\,G$ (potential) does external work.

For the energy in the condition Q:

$O\,A_1\,K\,E$ (kinetic) received unchanged from energy in condition P.
$G\,C_1\,D\,J$ (potential) received unchanged from energy in condition P.
$B_1\,G\,J\,K$ (potential) received from kinetic energy in condition P.

Fig. (7) represents similarly the partitions and transfers for the operation $P\,Q$ as above referred to. In this case the energy is increased by $H\,C_1\,D_1\,D$ and decreased by $A_1\,A\,B\,C\,H\,B_1$. Hence the net change is the difference of these two. It will be noted in such case that the hatchings for these parts run in different directions. The energy, on the whole, is evidently increased. The heat absorbed is represented by $P\,Q\,D_1\,D$. Hence the external work *done* will be represented by $P\,Q\,D_1\,D - (H\,C_1\,D_1\,D - A_1\,A\,B\,C\,H\,B_1)$ or by the sum of the two areas $(A_1\,A\,B\,C\,H\,B_1 + H\,P\,Q\,C_1)$.

In the same manner as before we have the following partitions:

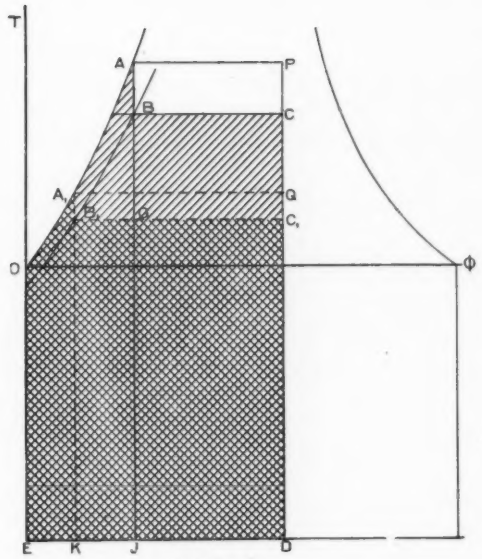


FIG 6

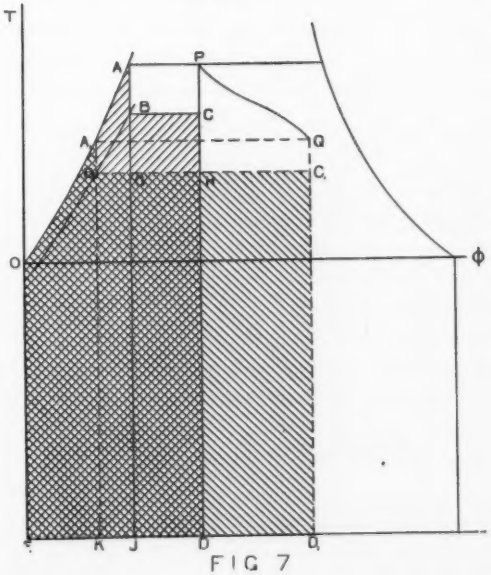


FIG 7

For the external work:

$A_1\ A\ G\ B$ done at the expense of the kinetic energy in condition *P*.

$B\ C\ H\ G$ done at the expense of the potential energy in condition *P*.

$P\ Q\ C_1\ H$ done at the expense of the heat absorbed.

For the heat absorbed:

$P\ Q\ D_1\ D$ = total amount.

$P\ Q\ C_1\ H$ goes to the performance of external work.

$H\ C_1\ D_1\ D$ goes to the increase of internal energy.

For the energy in the condition P:

$O\ A_1\ K\ E$ (kinetic) remains unchanged.

$G\ H\ D\ J$ (potential) remains unchanged.

$A_1\ A\ G\ B$ (kinetic) does external work.

$B\ C\ H\ G$ (potential) does external work.

$B_1\ G\ J\ K$ is transformed from kinetic to potential.

For the energy in the condition Q:

$O\ A_1\ K\ E$ (kinetic) comes from kinetic energy in condition *P*.

$B_1\ G\ J\ K$ (potential) comes from kinetic energy in condition *P*.

$G\ H\ D\ J$ (potential) comes from potential energy in condition *P*.

$H\ C_1\ D_1\ D$ (potential) comes from the heat added.

Fig. (8) represents similarly the exchanges and partitions for a change $P\ Q$, involving decrease of both φ and T. In this case the energy is decreased by $A_1\ A\ B\ C\ D\ D_1\ C_1\ B_1$, all hatched, as noted, in the same direction. The heat rejected is represented by $Q\ P\ D\ D_1$. Hence the external work done is represented by the difference in these areas or by $A_1\ A\ B\ F\ C_1\ B_1 - Q\ P\ C\ F$. In this case the decrease of energy is greater than the heat rejected, and we may therefore consider the external work as done entirely at the expense of the energy, the sum of the heat rejected plus the work done equaling the decrease of energy, as shown by the equations above.

In the same manner as before, we have the following partitions:

For the external work:

$A_1\ A\ B\ F\ C_1\ B_1 - Q\ P\ C\ F$ done at the expense of the energy.

For the heat rejected:

$P\ Q\ D_1\ D$ = total amount.

$F\ C\ D\ D_1$ comes from the potential energy of the body in the state P.

$Q\ P\ C\ F$ comes from the energy $A_1\ A\ B\ F\ C_1\ B_1$.

For the energy in the condition P:

$F\ C\ D\ D_1$ (potential) is rejected as heat.

$A_1\ A\ B\ F\ C_1\ D_1$ (kinetic and potential) is rejected partly as work and partly as heat.

$B_1\ C_1\ D_1\ K$ (potential) remains unchanged.

$O\ A_1\ K\ E$ (kinetic) remains unchanged.

For the energy in the condition Q:

$O\ A_1\ K\ E$ (kinetic) comes from kinetic energy of condition P.

$B_1\ G\ J\ K$ (potential) comes from kinetic energy of condition P.

$G C_1\ D_1\ J$ (potential) comes from potential energy of condition P.

For operations in the inverse direction $Q\ P$ in any of these cases, the exchanges and partitions are similar throughout, though reversed in character.

For an isothermal change $A\ P$, Fig. (6), the increase in energy is represented by $B\ C\ D\ J$ and the heat absorbed by $A\ P\ D\ J$, and, therefore, the external work by $A\ P\ C\ B$, as we have already seen.

DIAGRAM FOR SUPERHEATED STEAM.

Considering superheated steam as a perfect gas with constant specific heat at constant pressure $= c_1$, we have for any such change:

$$dH = Td\varphi = c_1 dT,$$

$$d\varphi = c_1 \frac{dT}{T},$$

$$\varphi] = c_1 \log T],$$

$$\Delta\varphi = c_1 \log \frac{T_2}{T_1} = c_1 \log \frac{V_2}{V_1}. \quad . \quad . \quad . \quad . \quad (21)$$

The lines showing the relation between φ and T for constant pressure will therefore be logarithmic curves, as shown by $L\ V$

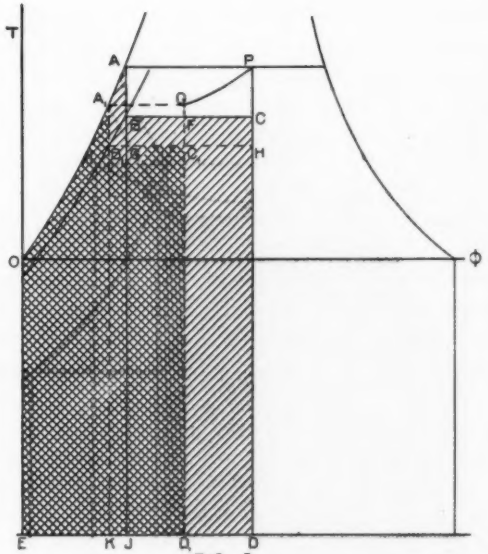


FIG 8

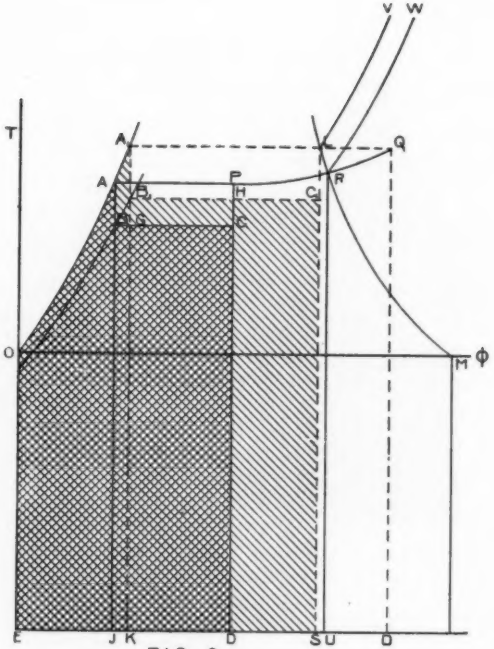


FIG 9

and *R W*, Fig. (9). In the actual case the passage of the substance from dry saturated vapor to superheated vapor is not sudden, and there should be no sudden change in the direction of the curves at the points of dry saturation. The properties which give the logarithmic curve may presumably be assumed to exist at temperatures from 5° to 20° beyond the temperature of saturation, according to the temperature, the former for low, the latter for high temperatures. Due, however, to a lack of experimental information, we do not know the exact history of the heat required in passing from the saturated to the superheated condition. No error significant in engineering work, however, is likely to be made by discarding this slight departure and taking the lines of constant pressure for superheated vapor as logarithmic curves, starting each from the saturated steam line, as shown. The form and disposition of the curves then point to the following conclusions:

(1) Increase of φ at constant pressure carried into the region of superheated vapor is accompanied by increase of temperature.

(2) Increase of φ at constant temperature carried into the region of superheated vapor is accompanied by decrease of pressure.

(3) Adiabatic expansion of superheated vapor is accompanied by a decrease of the extent of superheat, and an approach to the condition of saturation, and *vice versa*.

(4) Isothermal expansion of superheated vapor is accompanied by an increase in the extent of superheat and a departure from the condition of saturation, and *vice versa*.

In a perfect gas there is no change in the potential energy, while the kinetic energy is directly proportional to absolute temperature, or T. Hence in the present case the isothermals may also be taken as iso-energics. The energy of any point Q, Fig. (9), may therefore be determined by moving back on an isothermal to the point L, and then taking the energy for this condition, as above explained. The difference in energy at two points will then be given in the same way as for the difference at two points on $L\ M$. In this way operations may be extended across the line $L\ M$, and the heat exchanges and partitions determined

as before. Thus let $P\,Q$ denote any operation. The energy at P is hatched up and to the right, and that at Q or L up and to the left. The singly hatched part then shows the increase of energy, and, as before, the following partitions are readily seen:

For the external work:

$P\,Q\,D_1\,S\,C_1\,H - A\,A_1\,B_1\,H\,C\,B$ all from heat added.

For the heat added:

$P\,Q\,D_1\,D =$ total amount.

$P\,R\,U\,D$ absorbed in carrying the substance to the condition of saturation.

$R\,Q\,D_1\,U$ absorbed in the operation of superheating.

For the energy in the condition P:

$O\,A\,J\,E$ (kinetic) unchanged.

$B\,G\,K\,J$ (potential) transferred to kinetic.

$G\,C\,D\,K$ (potential) unchanged.

For the energy in the condition Q:

$O\,A\,J\,E$ (kinetic) unchanged.

$A\,A_1\,G\,B$ (kinetic) from heat added.

$B\,G\,K\,J$ (kinetic) transferred from potential.

$G\,C\,D\,K$ (potential) unchanged.

$B_1\,C_1\,S\,D\,C\,G$ (potential) from heat added.

SIMPLE PROBLEMS.

The complete diagram shows the simultaneous relation between p, v, T, φ and x, and also the partition of the heat required to produce one pound of the substance in any condition represented by a point on the diagram, and likewise the total heat and the partition of the heat corresponding to any change in the conditions. The result of any given change in any of those quantities is therefore readily seen.

Thus, for example, for high values of x it is seen that expansion at constant φ or adiabatic expansion is accompanied by a decreasing value of x and hence by liquefaction, while for small values of x, adiabatic expansion is accompanied by increase in

the value of x, and hence by vaporization. The boundary between these regions is the null curve, as already noted. The diagram shows also the conditions which must be fulfilled for expansion without change of quality, or for change in any desired degree.

As numerical examples we may take the following:

(1) Given one pound steam and water at $t = 320$ and $x = .8$ Adiabatic expansion takes place and t falls to 280. Find resulting values of x and v. Answer, $x = .78$, $v = 6.38$.

(2) Given one pound as in (1). To what volume must it expand adiabatically in order to reduce the value of x to .7? Answer, 67.9 cubic feet.

(3) Given one pound as in (1). Let it expand at constant quality until $t = 280$. Find change in v and φ. Answer, 2.93 and .03.

(4) Given one pound as in (1). It is carried by superheating at constant T to a point where its pressure is 20.8 pounds per square inch. Find the value of φ. Answer, 1.77.

(5) Given one pound as in (1). It is carried by superheating at constant p to a point where the entropy is 1.65. Find the T. Answer, 400°.

(6) One pound of steam gas at $t = 320$ and $p = 35.5$ expands adiabatically. Find the temperature at which it becoms saturated. Answer, 233°.

(7) One pound of steam gas at $p = 120$ and superheated 50° expands adiabatically. Find the temperature and pressure at which it becomes saturated. Answer, 310°.

(8) One pound of steam gas as in (7) expands at constant pressure to $t = 370°$. Find decrease in φ. Answer, .013.

Such examples as the above may be readily solved by means of a diagram similar to Fig. 5, but of larger size and carefully constructed to scale, with the various lines drawn as above described.

IRREVERSIBLE OPERATIONS.

In operations of this character where the irreversibility involves the pressure, as, for example, in a more or less complete free expansion, the external pressure p' is less than the internal

pressure p, and the external work done, $p'dv$, is less than the work pdv, which might be obtained by a reversible process. The difference $\int (p-p')\,dv$ may have, according to the conditions, any value from o to $\int p\,dv$, and its existence is the fundamentally characteristic feature of such operations as we have now to consider.

The conservation of energy gives us the general equation: $\Delta H' = \Delta E + \int p'dv$, and hence in such case $\Delta H'$ for a given change is less than if the operation were reversible. If the conditions are sufficiently known so that any one of these three can be determined, the relation between the others is known, or if any two may be found, the third becomes thereby determined. Writing W and W' for the values of the external work in the two cases, we have as above:

$$\Delta H' = \Delta E + W'. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (22)$$

also
$$\int T d\varphi = \Delta E + W = \Delta\varphi. \quad . \quad . \quad . \quad . \quad . \quad (23)$$

hence
$$\Delta H' = \int T d\varphi - (W - W'). \quad . \quad . \quad . \quad . \quad (24)$$

It therefore appears that the heat involved in such an operation is no longer equal to $\int T d\varphi$ or to the area under the path in a $T\varphi$ diagram, but is less than such amount by the difference $(W-W')$ or $\int (p-p')\,dv$. It follows that the relation of the lines of the diagram to the heat interchanges is modified, and care must be used in the interpretation and use of the diagram for such purposes. Thus if $B\,C$, Fig. (2), represents an irreversible change, B and C having the same entropy, we shall have from (24) $H' = -(W-W')$ or heat must be abstracted. An isentropic path or path of constant entropy is therefore no longer an adiabatic path or path of no heat transfer. An adiabatic path conversely will correspond to a change in entropy, and is represented, for

example, at $H C$. By a change of φ in this connection it must be understood that a change in the fundamental conditions p, v and T is implied, carrying with it a change in φ, but not necessarily brought about or accompanied by a change of heat. In particular it may be noted that a free expansion into a vacuum in a non-conducting chamber would involve no heat transfer and no external work, and hence no change of energy, and hence, with a perfect gas, no change of temperature. The adiabatic and isothermal paths would therefore in such case become the same. For such a change with any substance in general the result would be found by starting at the initial point and following along an isenergic path a distance corresponding to the change in volume. The final point would then give the resultant values of T and φ. Thus, for example, with steam and water let $t = 350°$, $x = .4$.

Suppose a free expansion into a vacuum by which the volume is increased 50 per cent. Required, the resultant conditions. Answer, $t = 322°$, $x = .425$.

In general it appears that free expansion will result, in greater or less degree, in loss of external work and gain in entropy.

APPLICATION TO STEAM ENGINE CYCLES.

Let us first assume an ideal cycle, as follows:

Adiabatic conditions throughout.

Expansion to exhaust pressure.

Compression to initial pressure.

An indicator card with no rounding off of corners.

The steam present in the cylinder must be considered under two heads, as follows:

(1) The cushion steam q.

(2) The steam feed Q.

In Fig. (10) let $B\ C\ D\ E$ represent such a diagram, $O\ A$ being the line of zero volume and $O\ K$ that of zero pressure. Then $A\ B$ or $G\ H$ represents clearance volume and $H\ D$ cylinder volume. At the point of exhaust closure E the volume and pressure of the cushion steam are $G\ E$ and $J\ E$. By the aid of steam tables and the assumption of a quality or value of x, the quantity q may be determined. The steam feed Q is found from the known or

determined water rate of the engine. We have now to examine the relation between p and v for each of these amounts of steam. First taking Q at the point E, we find it wholly condensed, and therefore with a volume practically o. In this condition we suppose it fed to the boiler, where we may consider that it is raised as a whole to the upper temperature and then vaporized to the quality of the steam in the boiler. Suppose next that in this condition it is transferred under its pressure p to the cylinder and there mingled with q, which for the present we assume to be saturated at this temperature and pressure. At the end of this operation Q will occupy the volume $B\ C$, and will be more or less completely vaporized, as determined by its quality. We then have the entire quantity $(Q + q)$ in the cylinder with volume $A\ C$. This quantity then expands adiabatically according to the path $C\ D$. It is fair to assume that in such case each and all parts expand adiabatically, and hence that q undergoes adiabatic expansion according to volumes given by the curve $B\ E$ and Q, according to volumes given by the intercepts between $D\ E$ and $C\ D$. At D the exhaust valve opens and Q is gradually forced out and condensed, its pressure remaining constant and its volume decreasing to the point E, where it is all again liquid, and we reach the initial point. The cycle of Q is thus seen to be partly in the boiler and partly in the cylinder. The conditions in the former are determined by the temperature and quality, and the indicator card will give at all points in the latter the pressure and volume, and hence the temperature, quality and entropy.

Turning now to q we have already seen that $B\ E$ is an adiabatic expansion line for this quantity. Assuming its quality to remain unchanged throughout the exhaust $D\ E$, it follows that adiabatic compression will carry q back over the same path $E\ B$. Hence the cycle for q is simply $B\ E \ldots E\ B$, or expansion and compression down and up the same line. It follows that the cushion steam may be considered as a part of the mechanism of the engine, and that we are not concerned with its cycle in the thermodynamic history of Q, except in so far as it determines the line $B\ E$ from which to measure the volumes of the steam feed Q.

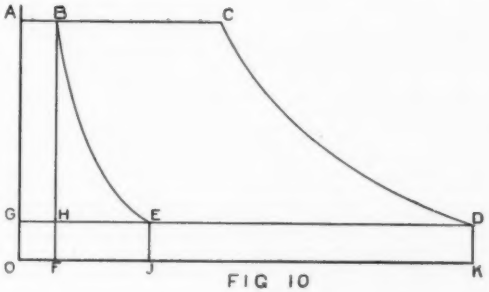


FIG 10

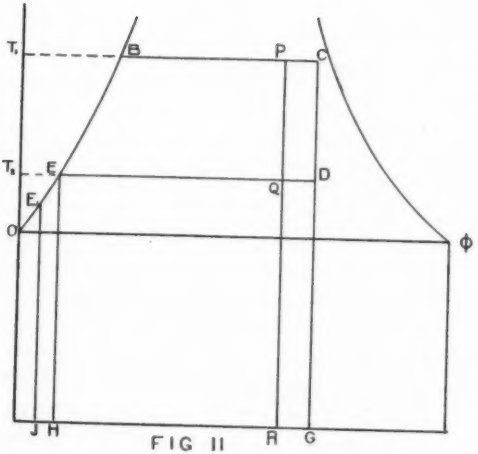


FIG 11

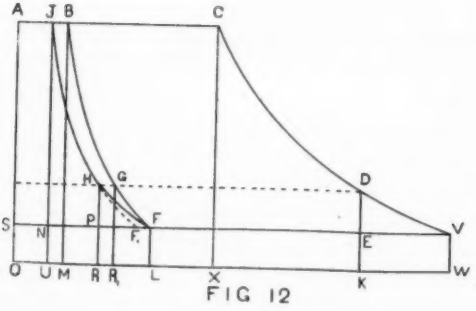


FIG 12

T Φ DIAGRAM CORRESPONDING TO THE ABOVE CYCLE.

It must be remembered that we are concerned simply with the $T\varphi$ history of the steam Q. Now the T is determined by the p and the φ at given T by the v, or by the value of x. For convenience it is preferable to reduce all quantities to the values for one pound, by dividing volumes by the pounds of steam feed Q per stroke. Hence $O\,T_2$ and $O\,T_1$, Fig. (11), being the values of T, corresponding to E and B, Fig. (10), the line $E\,B$, Fig. (11), represents the $T\varphi$ history of Q while in the boiler, and during elevation of temperature. During vaporization Q is considered as changing in volume from o to $B\,C$, Fig. (10). This, reduced to the volume for one pound, and divided by the volume of one pound saturated steam at the same temperature, will give the quality at C, Fig. (10), and hence locate the point C, Fig. (11). The adiabatic expansion $C\,D$ is represented by $C\,D$, Fig. (11), and the gradual condensation $D\,E$ by $D\,E$, Fig. (11), bringing us again to the initial point. The heat utilized is represented by $B\,C\,D\,E$, Fig. (11), and the heat required by $H\,E\,B\,C\,G$, and hence the efficiency, by the ratio of these two areas.

If the boiler should be fed not with the condensed steam at temperature T_2 but with water at a lower temperature, represented by E, then the operation is no longer a cycle. Q is introduced at E_1 and is heated to B, and so carried around as before and finally rejected in the condition represented at E. The heat utilized would be the same, but that required would be increased by $J\,E_1\,E\,H$, and the efficiency would be correspondingly decreased.

Incomplete Expansion.—We will now examine the modifications resulting from this condition, all other conditions remaining the same. Such a card is represented in Fig. (12) by $B\,C\,D\,E\,F$, in which, for convenience, we may consider $Q = 1$ pound. At the higher p and T, and after admission, let the cushiom steam q occupy a volume $A\,J$, and the steam feed Q a volume $J\,C$. Then $C\,D$ is an adiabatic of $(Q + q)$ and $J\,H$ of q. At this point the exhaust valve opens and free expansion takes place into the condenser accompanied by a sudden drop of pressure from D to E. This operation is irreversible, and the work done by q during such expansion will be less than for a reversible expansion between the

same limits of volume and pressure. Hence the decrease of energy will be less than for a reversible expansion, and the excess of energy in the final condition will give rise to an increase of volume in comparison with the reversible process. Hence the expansion of q from H down will be according to some line HF, lying to the right of HF_1, the adiabatic continuation of JH. SF is the volume of q shut in by the exhaust closure, and this will be compressed to the initial pressure according to the adiabatic path FGB. Now, if q at pressure OS had occupied the volume SF_1, as for the case of a complete expansion and compression cycle $JCUF_1$, adiabatic compression would have carried it up to J, and its quality at that point would be as determined by the existing conditions. But since at pressure OS, q occupies volume SF, its quality at F is higher than at F_1, and therefore the quality at B will be higher than at J, or higher than at the end of compression in a complete expansion and compression cycle.

In discussing the actual cycle $BCDEF$ we shall compare it with a cycle as just referred to, and as discussed under Fig. (10). For convenience such cycle will be taken as $BCVF$, Fig. (12). It will be remembered that for a cycle of this character we assumed the quality at the end of compression as saturated. Hence, making such assumption for the reversible cycle at B, it follows from what we have seen above that at the same point for the actual cycle the steam q will be superheated, and will therefore have a temperature higher than that corresponding to the pressure. On the entrance of Q an equalization will take place, q will lose its superheat, and the result will be a mixture of $(Q + q)$ at a resultant quality. During this operation q will decrease in volume to AJ, and is then ready for another cycle.

We have thus the history $JCDEFB$ for Q, in conjunction with the cycle $JHFGB$ for q, in each of which certain features are irreversible. We will now compare this combination with reversible cycles for Q and q, as referred to above, and in which steam of the same quality in the boiler is used.

Since q traverses a closed cycle, and since the only drain of heat from the source is through Q, and since the only way of doing external work is on the piston, it is evident that the inter-

changes between q and Q will mutually balance. We are therefore chiefly concerned with the heat drawn from the source and with the work done on the piston. Now, the total heat required to produce Q in the conditions at C is:

$$H = H_{T_1}^{T_2} + H_J^C.$$

of which the part $H_{T_1}^{T_2}$ denotes the heat required to change the temperature from T_1 to T_2 while the second denotes the heat of vaporization for a volume denoted by JC. Of this amount, as we have seen above, a part is furnished in the boiler while the remainder is transferred from q during the operation BJ. The amount thus furnished by q may be found as follows. We have, denoting energy by E,

$$E_B = E_F + MBFL,$$
$$E_J = E_F + (UJHR + PFLR),$$

Also $E_B - E_J = H_B^J - UJBM,$

Whence $H_B^J = JBGFPH.$

We may obtain this result more directly and without noting the intermediate details by remembering that the heat given up by q during BJ (the only part of its cycle which is not considered adiabatic) must equal the net work done upon it, or the difference between $UJBFL$, the total work done upon it, and $UJHPFL$, the work which it does. This is seen to be $JBFPH$, as before.

At the point C, therefore, Q will have more heat by this amount than would be the case were the cycle reversible, and in consequence its quality will be correspondingly higher.

Passing now to the operation DE, we have for Q heat rejected and work received from q, equal to $RPFL$. The heat rejected will equal the loss in energy plus the work received or:

$$H_E^D = E_D - E_E + PFLR.$$

We have then for the heat received in the boiler the value:

$$H = H_{T_1}^{T_2} + H_J^C - JBFPH.$$

The actual external work done, and hence the heat so transformed, is measured by $B\,C\,D\,E\,F$, and the efficiency is the ratio of this amount to the value of H above.

Let us now turn to the $T\varphi$ diagram for Q. We first lay down, as already described, the diagram for the reversible cycle, as above noted. In Fig. (13) this is shown by $F\,B\,C_1\,V_1\,F$, corresponding to $B\,C\,V\,F$, Fig. (12). It must not be supposed in Fig. (12), however, that the two cycles there represented imply the use of the same *amount* of steam. They simply are intended to give the characteristics of the two cycles under comparison. Now in the actual cycle of Fig. (12) the quality at C will be higher than for the reversible cycle, and hence the corresponding point in Fig. (13) will be at C, for example. The expansion line is represented by $C\,D$. The volume $E\,F$, Fig. (12), with the known pressure will suffice to determine the point E, Fig. (13), and other intermediate points on the line $D\,E$ may be determined as desired. It is readily seen that the areas $E\,D\,V$ on the two diagrams are equal, the one in heat the other in mechanical units. Now if the operation $D\,E$ were reversible the heat rejected would be represented by $H\,E\,D\,G$. Let us see to what such an amount of heat would correspond on the diagram of Fig. (12). We must suppose heat abstracted and the body compressed so that Q shall follow the same history of volume and pressure as in the actual case, and as determined by the lines $H\,F$ and $D\,E$. In such case the work done upon Q would be represented by $R\,H\,F\,L$, Fig. (12), and we should have for the heat rejected:

$$H = E_D - E_E + R\,H\,F\,L,$$

and this amount in Fig. (13) would be represented by $H\,E\,D\,G$. But, as seen above, the heat actually rejected by Q is represented by

$$H = E_D - E_E + P\,F\,L\,R.$$

Hence the difference in the two cases is represented by the area $H\,F\,P$, and hence in Fig. (13) the heat actually rejected will be represented by the area $H\,E\,D\,G$ decreased by $H\,F\,P$, Fig. (12). Let this decreased amount be represented by $H\,E_1\,D_1\,G$. The

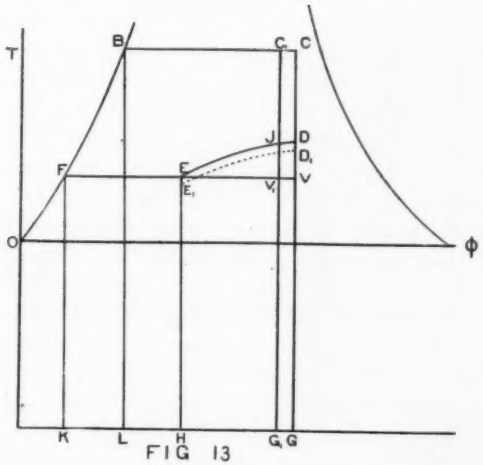


FIG 13

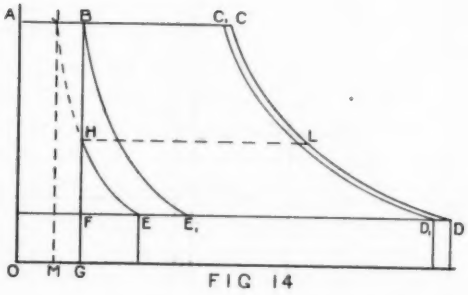


FIG 14

remaining line on the diagram $E F$ is the same for each cycle. Hence for the actual cycle the total heat required is $K F B C G$, of which $K F B C_1 G_1$ is provided in the boiler and $G_1 C_1 C G$ comes from q. The heat rejected, as we have seen, is represented by $K F E E_1 D_1 G$, and hence the total work done is $F B C D_1 E_1 E F$. Of this, however, an amount represented by $J B G F P H$, Fig. (12), or $G_1 C_1 C G$, Fig. (13), is done on q and not on the piston. Hence the net external work equals $F B C D_1 E_1 E F - G_1 C_1 C G$ or $F B C_1 V_1 - E J V_1 - G_1 J D G + E D D_1 E_1$. The heat actually absorbed in the boiler, as we have seen, is $K F B C_1 G_1$, and the efficiency will be as determined by the ratio of the net work to this amount. It thus appears that in the actual cycle a certain part of the total work of Q is given to q and by the latter given back to Q as heat, while only a part of the heat thus provided is re-transformed into work, the remainder being rejected, as shown by the diagram and by the negative term $- G_1 J D G$. The loss $E J V_1$ is due directly to the incomplete expansion. The added term $E_1 E D D_1$ is a decrease in the loss due to incomplete expansion, such decrease being due to the irreversibility of the line $D E$.

Incomplete compression with complete expansion.—Such a cycle is represented in Fig. (14) by $B C D E H$. At E the exhaust closes and the steam q is compressed up to H, where the steam valve opens and steam from the boiler enters. The steam q is then still further compressed up to the initial pressure, where it occupies the volume $A J$. This operation may be taken as reversible for q, and we may consider $E H J$ up and down as an adiabatic curve. Relative to Q, however, this path is irreversible, for the pressure and temperature do not correspond. We may most conveniently assume Q vaporized under pressure p to the given quality x in the boiler, thereby acquiring a volume V. The valve is then opened and it is transferred to the cylinder under its pressure p, thereby receiving the work $p V$. As the steam rushes in to the clearance space, q is compressed along the line $H J$ and the work $M J H G$ is done by Q on q. The work corresponding to a reversible change $B J$ is $M J B G$, and this equals the work which would be given Q during this part of the transfer into the cylinder. Hence

for the compression HJ the work done by Q is less than that received, and the surplus work will go into a further formation of vapor, thereby increasing the volume of Q and raising its quality. At the end of the admission let the volume be represented by JC, and let JC_1 represent the original volume at the quality in the boiler. Then the increase in volume is C_1C. Denote this by v. Then for the total work done we have:

$$p\,V - J\,B\,H + p\,v,$$

and for the excess of work received:

$$J\,B\,H - p\,v.$$

This will go into the energy of the additional vaporization, or we may otherwise consider JBH as representing the total work available for an increase of vaporization, of which the part pv goes to the external work and the remainder to the corresponding increase of energy. We naturally compare this cycle with that represented by $J\,C_1\,D_1\,E$ for the steam of original quality and with complete compression, and a study of the two diagrams will readily show their points of relative difference.

Turning now to the corresponding $T\varphi$ diagrams, we have in Fig. (15) $A\,C\,E_1\,F_1$ for the reversible cycle $J\,C_1\,D_1\,E$ of Fig. (14). For the actual cycle the point E corresponds to the point C and represents the increased quality due to the added vaporization. It must be borne in mind, however, that E_1E represents an irreversible process, and that no heat enters or leaves Q during this operation, so that it is adiabatic in character. The regular adiabatic expansion line is then represented by EF, and the exhaust line by FA, as usual. It follows that the heat required is represented by the area $A\,C\,E_1\,F_1$, and that rejected by $JAFC$. The amount utilized is then represented by their difference, or $A\,C\,E_1\,F_1 - C_1\,F_1\,F\,C$. It is readily seen that $C_1\,E_1\,E\,C$ equals JBH, Fig. (14), and that the irreversibility increases the heat rejected by a fraction of this amount represented by $CF \div CE$, while the heat absorbed remains the same, and the result is a loss in efficiency. We may also in Fig. (14) consider a reversible cycle $B\,C\,D\,E\,H$. To obtain such a cycle it would be simply necessary to begin the vapor-

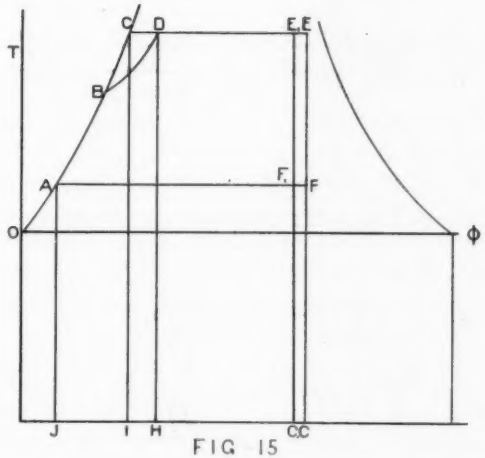


FIG 15

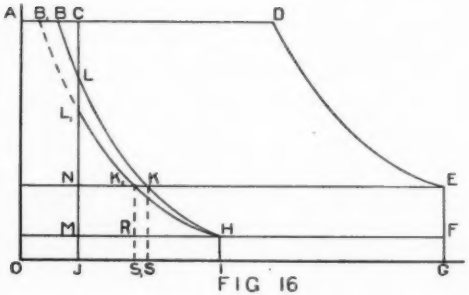


FIG 16

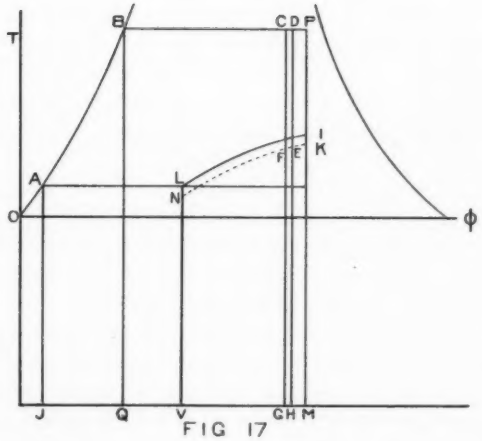


FIG 17

ization of Q at pressure $G\,H$ and continue it at increasing pressures until the clearance space was completely filled. In Fig. (15) the diagram per pound for such a cycle would be $A\,B\,D\,E_1\,F_1$.

Incomplete Expansion and Compression.—Both of these features may be combined, as indicated in Fig. (16) by $C\,D\,E\,F\,H\,L$. By reasoning similar to that for the preceding case with incomplete expansion we conclude that q will go through a cycle somewhat like $H\,L\,B\,B_1\,K_1\,H$, in which $H\,L\,B$ is an adiabatic compression line, $B_1\,K_1$ an adiabatic expansion line, and $K_1\,H$ a free expansion line, as previously explained.

The $T\,\varphi$ diagram for this case is readily derived from what has been already given for the two essential features separately, and may be represented as in Fig. (17). $B\,C$ represents the quality of the steam in the boiler. $C\,D$ the added vaporization due to the work $B\,C\,L$, as in Fig. (14). It will be remembered that $C\,D$ is here an adiabatic line. $D\,P$ represents the additional vaporization due to the heat $B_1\,B\,K\,H\,R\,K_1$ transferred from q. The remainder of the diagram is similar to Fig. (12). The total heat absorbed is then $J\,A\,B\,C\,G + H\,D\,P\,M$. The heat rejected is $J\,A\,L\,N\,K\,M$. The total external work is their difference. Of this total, an amount represented by $B_1\,B\,K\,H\,R\,K_1$, Fig. (16), or $H\,D\,P\,M$, Fig. (17), is not done on the piston but on q. The net external work will be therefore $A\,B\,C\,F\,N\,L - H\,E\,K\,M$.

Wire-Drawing During Admission.—This is an irreversible operation for that part of Q outside the cylinder, and results in a loss of temperature and pressure without the production of the normal amount of external work. The indications of the card refer, furthermore, only to that part of Q within the cylinder, and the pressure and temperature of this part are different from those of the part outside. Q is, therefore, not homogeneous, and no line on a $T\,\varphi$ diagram can represent its $T\,\varphi$ relation during such operation, simply because it is not in the same condition throughout. If $A\,C$, Fig. (18), is the admission line of a card and $A\,C$, Fig. (19), is the corresponding line derived from the card as above explained, then the latter line will not represent the $T\,\varphi$ relationship of Q during this period, nor will any

other line, for reasons indicated above. At any point in general for a given value of T the φ will be greater than as given by Fig. (19), because the derived value assumes the temperature uniform and the same as that of the vapor in the cylinder, while, on the contrary, the part within the boiler must be considered as water with the temperature therein, and hence higher than that of the cylinder. If any given substance receives work w_1 and does work w_2 then we have for the relation between heat, energy and work —

$$J H = J E - w_1 + w_2 = J E - (w_1 - w_2). \quad . \quad . \quad (22)$$

Now assume the following operations:

(1) The vaporization of Q in the boiler to a quality or volume to be determined later. Let $A B$ and $E A$, Fig. (18), be the volume and pressure, and let the temperature and entropy be denoted by the point B, Fig. (19).

(2) The transfer of this through the valve to the cylinder under pressure $P_1 = E A$ acting through a volume $A B$, thereby giving it the work $p_1 A B = A B D E = w_1$.

(3) Consequent on this, and due to the wire-drawing, the performance of work in the cylinder corresponding to the law of pressure along $A C$ and amounting to $A C F E = w_2$. Now, if the conditions are adiabatic we shall have from (22) above:

$$J E = (w_1 - w_2).$$

The values of the energy at B and C, Fig. (19), are definite, and hence B can be so determined that the change in energy shall equal $(w_1 - w_2)$ and thus fulfil the conditions proposed. This series of operations may then be considered as the representative of those actually occurring.

It thus appears that in Fig. (18) we absorb heat corresponding to the production of the vapor in the condition B, but at the end of admission have performed external work $A C F E$ instead of $A B D E$, and have brought the vapor to the condition C.

Transformed to the $T\varphi$ diagram we have for the heat required for operation (1) the area $A B R E H$. The transfer to the cylinder is represented by the irreversible adiabatic $B C$ (not here vertical).

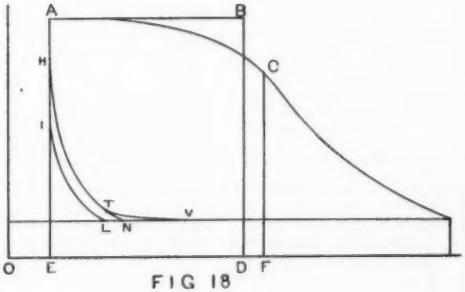


FIG 18

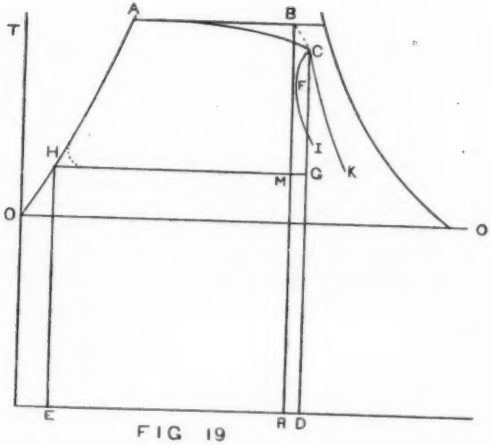


FIG 19

Representing the remainder of the cycle by CGH as usual, we have represented the effect of wire-drawing on an otherwise reversible cycle. The heat rejected is represented by $HGDE$, and hence the heat utilized equals $ABREH - HGDE$ or $ABMH - MGDR$. The efficiency will equal the ratio of this quantity to the heat absorbed, or $ABREH$.

The representation of the effect due to wire-drawing is thus seen to be complete so far as heat relations are concerned, but from the complex nature of the exchanges the amount of effect in any given case will require detailed examination. It is clear, however, that the result will be prejudicial as compared with the introduction of the same quantity Q without loss of pressure.

Rounding of the Corner at Cut-off.—This is a more pronounced local wire-drawing, irreversible, and productive of effects as just noted.

Rounding of the Corner at Exhaust.—This corresponds to a delayed or throttled free expansion, as already noted.

Rounding of the Corner at Compression.—This is a reversible modification whose effect is to increase the pressure at the point of complete closure, and hence to increase the amount of steam shut in for compression. Thus if the exhaust valve closes suddenly at L, Fig. (18), the compression line would be L 1. With the gradual closure of the valve the pressure rises along the line VT to the point of complete closure T and then along the compression line TH. The path of q is thus up and down HN, and the horizontal intercepts between TN and TV will give the volumes of Q during this part of the cycle. This path transferred to the $T\varphi$ diagram, Fig. (19), will give a rounding of the corner at H, implying a rejection of heat at a temperature higher than that for the line HM. Comparing with the compression line HN, Fig. (18), the additional heat rejected will go into the feed water, and the corner cut off may therefore be considered as subtracted both from the heat required and from the heat utilized. This will, of course, result in a loss of efficiency.

Vaporization, Incomplete, Complete, or Superheated.—These conditions will be determined by the volume of one pound at the given pressure, or by the quality, and hence by the location of

the point within, on, or beyond the saturated steam line. The condition of the steam within the boiler should be thus laid down as indicated by the points E and I, Fig. (20).

Initial Condensation.—This affects the quality of Q at the end of admission, and its results are therefore shown by the location of the point as compared with that for the conditions within the boiler. Thus in Fig. (11) let $B\ C$ represent the conditions in the boiler, and let $B\ P$ represent the volume in the cylinder as decreased by initial condensation. Then the remainder of the diagram being as indicated by $P\ Q\ E\ B$ for complete expansion, the heat actually utilized will be $P\ B\ Q\ E$, the loss in heat utilized will be $P\ C\ D\ Q$, and the heat required will be $H\ E\ B\ C\ Q$, as usual. Reference may also be made to the effects of initial condensation, as shown in the diagrams of Fig. (20).

Condensation During Expansion.—This will result in a line $C\ F$, Fig. (19), instead of $C\ G$.

Re-evaporation During Expansion.—This will carry the expansion line to the right, as shown by $F\ I$. If sufficient heat is provided, as by a jacket, the expansion line may lie on the right of $C\ G$ as shown $C\ K$. See also $F\ G$, Fig. (20).

Since it is relatively more advantageous to receive heat at the highest temperature than at a decreasing series of temperatures, it follows that it would be relatively more advantageous to prevent initial condensation than to produce an expansion line similar to $C\ K$, Fig. (19).

COMPRESSORS.

For the operation of compressors either with condensible vapors or non-condensing gases the $T\varphi$ diagrams are readily determined in the manner explained in the preceding cases for the steam engine, and no additional principles are involved and no further explanation should be required.

MULTIPLE CYLINDER ENGINES.

In the preceding treatment of the $T\varphi$ diagram it will have been noted that its essential and necessary feature is the representation of the values of T and φ for a given constant amount of steam Q

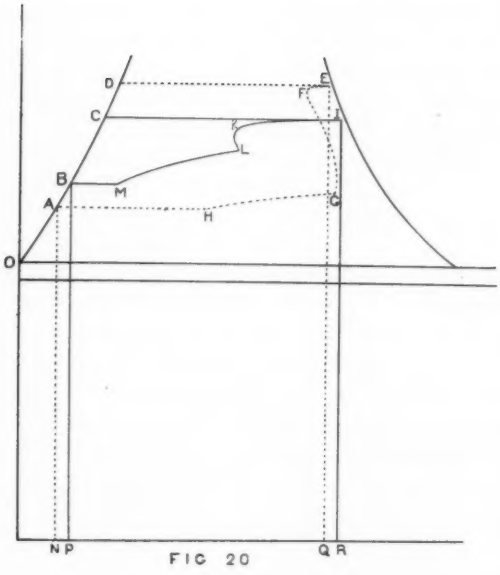


FIG 20

throughout its cycle in the boiler and engine. The application of the diagram in this way to the details of the operation of a multiple expansion engine is very limited, since the quantity Q no longer has a continuous separate existence throughout the entire cycle. A given charge or amount of steam feed Q enters per stroke, but this is subdivided and united with various other quantities in the cylinders and receivers with different values of p and T, so that no diagram can mean for the details of the operation in a multiple expansion engine what the diagrams above considered do for a simple engine.

For any part of the cycle for which the amount Q remains constant and can be identified, the $T\varphi$ diagram may be derived in the same manner and with the same significance as in the cases already explained. Also for the entire cycle a $T\varphi$ diagram may be derived from the combined indicator diagram considered and treated as a single diagram in the manner already described.

In Fig. (20) are shown a pair of diagrams derived from actual indicator cards. The one in full lines is from a small uneconomical engine working over a small temperature range and with excessive initial condensation, as indicated by $I\,K$, the point I denoting the condition of the steam at the boiler. The expansion is also quite incomplete, as indicated by $L\,M$. The diagram in dotted lines is from a triple-expansion engine designed with especial reference to economy. The initial condensation, as shown by $E\,F$ is much less, while the expansion is nearly complete, as indicated by $G\,H$. The expansion curve $F\,G$ is carried to the right of the vertical or adiabatic line by heat absorbed from the jackets, and partly, perhaps, from the heat stored in the H.P. wall during the condensation indicated at $E\,F$. A complete account of the heat required in this case would, therefore, require attention to the steam condensed in the jackets. One of these engines required about 40 pounds of water per I.H.P. per hour, the other about 13. These diagrams show plainly the reasons for the great superiority of one over the other.

THE SUBMARINE TORPEDO BOAT *PLUNGER*.

By J. Alvah Scott, Esq., Associate.

[Paper presented at Annual Meeting.]

The Holland submarine torpedo boat, which is building for the United States Navy at the yard of the Columbian Iron Works and Dry Dock Company, at Baltimore, Md., was launched August 7, 1897, at noon, and was christened the *Plunger*.

The boat is 84 feet long by 11 feet 6 inches diameter, and is circular in section.

The displacement when on the surface is 149 tons, and when awash or submerged 165 tons; reserve buoyancy when submerged about one-quarter of a ton.

The speed on the surface is to be 15 knots; while awash with one foot of the turret above water, 14 knots with steam machinery, and to have a duration of twelve hours at this speed; while totally submerged and running with electrical machinery a speed of 8 knots must be maintained at a minimum duration of six hours.

Amidships there is a turret of 4 inches thickness, which is 3 feet 10½ inches wide by 9 feet long, and extending 4 feet above the hull proper. There is a superstructure extending fore and aft of the turret, forming a fairwater; there is also a fairwater superstructure forming a cutwater at the bow.

The nose piece, or under-water bow, has two openings through which the bow torpedoes are to be discharged, and an opening, top and bottom, for the bow downhaul screw. There is a similar downhaul screw in a well built in the stern of the boat. These screws are for forcing the boat under water when not under way, maintaining the boat at a level keel and a given depth when located in one place, or for bringing the boat to the surface quickly.

The boat is fitted with the regular hand steering gear; it also has an automatic device for steering in a straight line horizontally, when submerged, and an apparatus for diving the boat to any predetermined depth, as well as maintaining the depth automatically when running submerged. The boat can also be dived and steered vertically by hand. It is fitted with a *camera lucida* for taking observations above the surface when running slightly submerged.

The hull is of sufficient strength to allow the boat to be submerged to the depth of 75 feet. The outside plating is of steel $\frac{1}{2}$ inch in thickness amidships tapering to $\frac{3}{8}$ inch at the ends, and the frames are 5×3 inches amidships and $3\frac{1}{2} \times 3$ inches at the end.

The hull is divided into eighteen water-tight compartments, sixteen of which form tanks in the double shell of the boat and two are main compartments.

The first main compartment extends from the forward trimming tank to the after end of the machinery space, taking in the torpedo, forward battery, boiler and engine rooms and electrical machinery spaces. The after compartment contains the air reservoirs, the after storage batteries, the vertical rudder steering gear and after downhaul screw motor, and extends from the after part of the machinery space to the after trimming tank.

Six of the double shell compartments form the submerging tanks and have a capacity of sixteen tons. Three of these tanks are forward and three aft. The extreme end ones in each case form the trimming tanks.

Eight of the amidship compartments will contain the oil fuel, with a capacity of twelve tons. One tank amidship will contain about a ton and a half of fresh water, while another, which is near the bow, will be used for compensating water to be taken in for the torpedoes as they are discharged.

The oil fuel will be compensated for in the tank as it is used in running.

There are two bow torpedo tubes for discharging submerged torpedoes, five of which are carried. Both tubes can be discharged at once.

In the stern of the boat there are located four rudders, two for steering on a horizontal plane and two on a vertical. Using the rudders in pairs balances their action, which is necessary in order to have the automatic devices work correctly.

The boat is propelled while running on the surface by steam machinery and while under water by electric machinery. The steam machinery consists of one water-tube boiler of the Mosher type, containing about 3,000 square feet of heating surface, and is fitted with the Consolidated Gas Fuel Co.'s system for oil fuel, which is capable of consuming 2,000 pounds of oil per hour for twelve hours.

There are three engines, two main engines on the side shafts, of 600-horse power each, and one auxiliary engine on the center shaft, of 300-horse power, which can be used for cruising, dynamo engine, or as extra power for speeding in connection with the main engines.

All three engines are of the three-cylinder, triple-expansion vertical type. The main engine cylinders are 10, 16 and 25 inches in diameter by 15 inches stroke, while the auxiliary engine has cylinders 8, 12 and 18 inches diameter by 9 inches stroke.

The condenser is of steel, oblong in section, and contains 1,300 square feet of cooling surface; the circulating water passes through the tubes, and circulation is produced by a scoop while under way and by an auxiliary circulating pump while running at the dock.

The electrical machinery is composed of one main motor of 70-horse power for propelling the boat submerged, and it can operate either the side or center shafts. It is supplied with a current of 96 volts by storage batteries with 48 cells, 10 cells of which are in the after compartment and 38 in the forward compartment. Each group of cells is in a tight casing which is ventilated by an electrical pump, which prevents the fumes from getting into the boat. This motor can be reversed and converted into a dynamo for recharging the batteries. These batteries are composed of special Planté-Chloride cells, each weighing about 1,000 pounds, and their combined capacity is 70-horse power for six hours.

In addition there are three 10-horse power motors, one of which operates the bow downhaul screw and the anchor windlass; one

the raising and lowering of the stack, which is situated in the after part of the turret, also for opening and closing the water-tight cover over the stack and the ventilating pump for discharging the vitiated air while submerged; and the third motor operates the after downhaul screws.

Fresh air is supplied to the boat from reservoirs containing 50 cubic feet of compressed air at 2,000 pounds pressure per square inch, through tanks containing it at 10 and 40 pounds pressure respectively, to which it is delivered through reducing valves from the main air reservoirs.

This compressed air is also used for blowing the water out of the trimming and submerging tanks, and for operating the automatic diving gear.

The air which is delivered into the boat for ventilating purposes is discharged through an automatic regulating valve capable of maintaining the atmosphere within one ounce pressure per square inch either way from normal atmosphere.

The smoke pipe and air duct are contained in one casing, the stack in the center and the air duct surrounding it, so arranged that it can be telescoped inside the turret before submerging the boat, over which an armored water-tight sliding door is closed by an electric motor above described.

Each of the four main submerging tanks has a 6-inch Kingston valve for flooding the tanks in submerging, which can be operated either by hand from the engine and torpedo rooms, or by compressed air from the turret, from which all operations in steering and submerging are performed. The manipulation of the downhaul screws is effected from controllers in the conning tower, while the operations of the stack and cover are controlled from the engine room. All steam machinery, of course, is handled from the engine room, as is also the controller of the main motor, while the steering and the handling of the automatic diving apparatus and depth regulator, as well as the hand diving gear, are all done in the conning tower. The *camera lucida* tube is situated just forward of the turret, so that it can be used by the officer in charge in the turret.

When the submerging tanks are full of water, the boat is in the

awash condition, with one foot of the turret out of water, which leaves about one-quarter ton reserve buoyancy, which, when the boat is under way, is steered under by the force of the headway, and when standing still is held under by the downhaul screws.

In emptying the submerging tanks, the water can be blown out by compressed air or be pumped out by a special bilge pump operated by the main electric motor, while in case of emergency it can be pumped out by hand by a pump on the conning tower platform operated from the conning tower.

When awash, with steam up, these tanks can be pumped out by the auxiliary feed pump.

From the above description it will be seen that the boat has three propellers, either or all of which can be operated by either steam or electric machinery.

The following is the "Schedule of Requirements" laid down by the Navy Department under which the boat is being built:

MOTIVE POWER WHEN RUNNING LIGHT OR AWASH.

Twin screws operated by triple-expansion steam engines capable of developing power sufficient to propel the vessel at the following speeds:

Fifteen knots when the vessel is in the light condition.

Fourteen knots when the vessel is in the awash condition, with a minimum endurance of twelve hours at this speed.

MOTIVE POWER WHEN SUBMERGED.

There shall be a battery of storage cells capable of supplying an electric current which will develop through the necessary motor and connections power sufficient to propel the vessel, when completely submerged, at a speed of 8 knots, with a minimum endurance of six (6) hours at this speed.

The steam power, electric dynamo and storage cells shall be so connected as to be readily reversible in their action, thus rendering it possible to recharge the cells from the dynamo, the steam engine being used as a prime motor. The electric power may also be connected directly to a propeller shaft placed in the axis of the boat, in addition to the connection with the main propeller shafts.

The electric motor may thus operate a special propeller, in addition to driving the main shafts independently of the steam engines.

The capacity of the electric storage cells shall be amply large to prevent injury or deterioration while giving off the power required to propel the vessel at a speed of 8 knots for six hours.

ARMAMENT.

Five automobile torpedoes and two expulsion tubes, with the necessary air plant, all to be supplied by the Government, but to be installed by the contractor, with the necessary fittings, upon plans approved by the Government.

Only the main expulsion tubes will be supplied by the Government, that portion of the tubes built into the hull of the vessel being furnished by the contractor, as well as all fittings for closing the ports. The contractor will also supply machinery for running out and in the impulse tubes should such machinery be found necessary.

PROTECTION.

1. Ability to reach a depth of 20 feet below the surface of the water within one (1) minute after the order is given to dive, the boat at the time floating light and running full speed ahead, the smoke stack being raised to its full height.

2. The power to dive to a depth of 20 feet within thirty seconds, the boat before diving running at full speed with steam power and having 3 feet of water over the hull; smoke stack being erect, as required in previous paragraph.

3. Complete submergence with 3 feet of water over the turret, the pilot obtaining a view over the water by means of a camera lucida in a tube that projects above the surface.

4. An armor turret rising to a total height of 4 feet above the hull, the pilot's head being protected by an armor cylinder of 8 inches thickness, or of such thickness as the Department may hereafter determine.

5. Complete double shell extending about three-quarters of the vessel's length aft from the stem, except where interrupted by the turret and companion ways, the space between being chiefly occupied by fuel bunkers and water-ballast tanks.

General requirements, in addition to the foregoing, guaranteed by the contractor, to be fulfilled under such tests as the Department may prescribe:

1. Sufficient structural strength, with a reasonable factor of safety, in order to withstand hydrostatic pressure at a depth of immersion of 75 feet.

2. Ample stability in both the surface and submerged conditions.

3. Automatic arrangements for preventing submergence beyond a predetermined depth.

4. Automatic compensation for stores or ammunition consumed, and independent mechanism for quickly correcting any variations in trim due to shifting of weights or other causes.

5. Efficient mechanical means for steering a fixed course.

6. Ample provision for the supply of pure air to the crew—this to be accomplished chemically, or by means of air stored under pressure in tanks.

7. Efficient apparatus, independent of air pumps or air pressure, for checking submergence and causing vessel to rise rapidly to the surface.

8. Ability to maintain an approximately fixed position, also a definite depth of submergence without undue expenditure of power.

9. Provision for escape of crew in the event of serious damage to hull or derangement of machinery.

Upon the completion of the vessel a test shall be made showing its capability of making submerged runs for a distance of two (2) miles, at the end of which a torpedo shall be discharged and strike a target 150 feet long and 16 feet deep, the upper edge being awash and placed at right angles to the course. During these submerged runs, the vessel shall not come to the surface more than three times from the time of starting until the discharge of the torpedo, the duration of each appearance not to exceed one (1) minute.

This, and such other tests as may be required by the Department in order to fully demonstrate the successful operation of the vessel and all its appurtenances and the fulfillment of the

specified guarantees, shall be made by and at the expense of the contractor, under the supervision of a board appointed by the Secretary of the Navy.

In lieu of premiums and penalties, the following speed allowances shall be made, within which the Department may accept the vessel at a reduced valuation to be determined by a board appointed by the Department:

For the light condition the speed shall not fall below thirteen and one-half (13½) knots.

For the awash condition the speed shall not fall below twelve and one-half (12½) knots.

For the submerged condition the speed shall not fall below six and one-half (6½) knots.

STATUS OF BOARDS ON CHANGES AS USUALLY CONSTITUTED UNDER THE CONTRACTS FOR CONSTRUCTION OF OUR NEW NAVY.

By William W. Varney, Esq., Associate.

[Paper presented at Annual Meeting.]

As many members of this Society are either directly or indirectly interested in this subject, either as contractors or members of such boards, I offer no apology for this paper, even if it does not treat primarily of an engineering subject.

In most, if not all, of the contracts for the construction of vessels for the United States Government entered into in recent years, we find a clause concerning alterations, changes and extra work, which reads in substance as follows: "* * * If changes are thus made, the actual cost thereof, and the damage caused thereby, shall be ascertained, estimated, and determined by a board of naval officers, appointed by the Secretary of the Navy, and that the party of the first part shall be bound by the determination of said board, or the majority thereof, as to the amount of increased or diminished compensation which the said party of the first part shall be entitled to receive, if any, in consequence of such change or changes. * * *"

As many of you are aware, the usual mode of procedure under the above clause is for the Secretary of the Navy to appoint three officers who are conversant with that branch of mechanics involved in doing the work, and usually one of such officers is the Government inspector in charge of that particular job. This board is given instructions from the Honorable Secretary for their guidance, and concerning which I will speak of later.

The usual practice concerning changes, or new work, is as follows: The contractor and the Government inspector each make separate estimates, and the same are forwarded to the De-

partment for its consideration, and the Department, in authorizing the work, orders that the ascertaining of the amount to be paid for the same shall be referred to "The Board on Changes." The board often considers the change on the basis of the two estimates above mentioned without further evidence, and decides accordingly, *i. e.*, if there is not much difference between the two estimates the board strikes a mean, and the contractor is satisfied, as his estimate is usually high enough to cover this cut. The above happy-go-lucky fashion is all very well if no one complains, and the same is not looked into legally; but in this paper I propose, in the absence of direct adjudication concerning the status of this board, to theorize somewhat concerning the same, as to what said board is, its proper method of procedure, and the binding effect of its decisions upon the parties to said contract, giving a few references to cases bearing out what I say.

What is this board? Is it strictly a board of arbitration selected by the parties mutually, or is it an arbitrary board appointed to award what they please irrespective of evidence, as some boards have apparently done in the past, believing it to be their privilege to conscientiously guess at the cost, or is it to be considered under the same head as the supervising architect acting as arbitrator?

In my opinion the legal status of this board is on a middle ground between a board of arbitration selected by both parties, and who know nothing concerning the matters involved, and the supervising architect selected exclusively by one party and using his own personal knowledge of the facts in addition to that which might be presented to him.

The personnel of the "Board on Changes" is not named in the contract, only its selection is limited to a certain class of persons known for their integrity and mental capacity to appreciate naval work, viz: naval officers (not necessarily those belonging to the mechanical arm of the service). The appointing of the said board is left to a particular official named in the contract by both parties, which official in the selection of the said board acts as the agent of both parties, the said official being the Honorable Sec-

retary of the Navy, a person who is supposed to have absolutely no personal interest in the matter. After the Secretary has appointed the said board, he has no further power over it concerning the interpretation of the contract, its mode of procedure, what it shall or shall not take into account, etc. The members are absolutely free from his jurisdiction pertaining to the said award in the case as submitted to them. The moment he interferes by special instruction or the like in any material way affecting the board's action concerning the matter before it, at that moment the actions of the board are voidable at the instance of the contractor, as they are then no longer a free and untrammeled board to act.

The difference between this board and the supervising architect, when he is made the arbitrator, is that the architect is a specific individual named in the contract, who is familiar with the work. In the Government case, the board is to be composed of indefinite individuals, selected from a certain class of an extremely high order of persons, who are more or less familiar with the uses to which the object of the contract is to be applied, but not necessarily the person having minute personal knowledge of all the details.

If all the members on the board had intimate personal knowledge of all of the facts, and one member did not give weight to or relate evidence with which he, and not the other members, is familiar, then the board as a whole might be considered on the plane with the supervising architect referred to above, but if any one of the members has to be enlightened concerning certain matters, that evidence must be produced in the presence of both parties, if they wish to be present, and if one member wishes to relate what he knows, it must be done in the presence of the parties, the same as any other evidence.

It will be seen that if any one member on the board is strange to the facts involved, then the proceedings of the board must necessarily assume the character of a Board of Arbitration, and usually this is the case, as at least one member of the board has not had the time and opportunity of familiarizing himself with the facts equally with the other members.

Having reached the conclusion that the "Board on Changes," as usually constituted, is a peculiarly constituted board, to which must be applied the law relating to Boards of Arbitration, which law is well settled in the United States, therefore we will treat the said board, after having been appointed by the Hon. Secretary, as an independent tribunal, not subject to his orders. As one party to the contract, he or his agents have no higher standing before the said board than the other party to the contract.

If, as is usually the case, the naval inspector, who may be also a member of the board, represents the Navy, presenting its case before the board, he must, when acting in such capacity, proceed as any non-member of the board would, submitting to cross-examination and the like when giving testimony, and not take advantage of his position as member of the board to explain his estimates in private to the board, and not give the contractor a chance to cross-examine him concerning the same. This would be fraud or misconduct towards the contractor, and would vitiate the entire proceedings.

The only law governing the board is the contract, which is the law between the parties, so far as the Honorable Secretary had the right to sign the same, taken in the light of the acts of Congress; and the duties of the board are exclusively to determine the cost of alteration and new work, as follows: "The actual cost thereof, and the damages caused thereby, shall be ascertained, estimated, and determined" by this board, and the only instructions which the Secretary can give them is the contract, as he is not the final judge as to matters of law between the parties. He can argue and present his views before the board as to what the law is upon an equal footing with the contractor, and on no other; therefore the sole questions for the board to determine are "the actual cost thereof, and the damage caused thereby." The above two expressions mean a great deal; they mean to make the contractor whole, or in the same position as though the changes had not taken place, taking into account profits, interest, plant charges, knocking off and beginning work, hiring men, insurance, and all of the incidental expenses of a large establish-

ment (which charges are, exclusive of profit in many large concerns, 100 per cent. of the labor bill).

The length of this paper prohibits me from occupying your attention further than to give brief extracts from a few of the many decisions bearing upon the subject, which extracts speak right to the point and much more forcibly than any mere theorizing could possibly do.

Shipman *v.* Fletcher, 82 Va., 601, Dec. 2d, 1886. Lacy, J.

Lacy, J.—" * * * They have made no award; they have blindly subscribed to the work of others; they did not have time to examine the subject themselves, and when they did come to do this perfunctory work they were so sensitive and dignified that they could not hear the parties, because they quarreled and were noisy, and so sat with closed doors as to the suitors in their court, as to one side at least.

" What a mockery of justice indeed; the principles upon which awards are upheld by the courts as final and binding on the parties, or are set aside for misconduct in the arbitrators or excess in the award are old and familiar, and but little controverted or questioned.

" This court, chosen by the parties, can exercise all the powers granted to them by the submission. This is the charter of their existence; they must proceed upon the fullest notice to all, and act only after hearing the evidence adduced before them in due course. Each party is not only entitled to present his own case, both by evidence and argument before the arbitrators, but he is also entitled to be present whenever witnesses or argument are heard on behalf of his opponent. * * *

" These rules or similar ones are founded in natural justice, and are absolutely necessary for the due administration of justice in every form whatever. * * *"

In Chaplin *v.* Kerwan, 1 Dallas, 187, the award was set aside because the evidence of one witness, produced by one party, was taken in the absence of the other party to the controversy. The rule, says Mr. Morse, requiring him (the arbitrator) to hear nothing on behalf of either party, unless the other party is pres-

ent, or has distinctly assented to his doing so, is generally very rigidly enforced.—Morse on Arbitration, 126.

Lewis *et al. v.* Chicago, S. F. & C. R'y Co., 49 Fed. Rep., 708; Circuit Court, E. D. Mo., 1891. (R. R. contract.)

"* * * The second clause in the contract, declaring that the engineer's measurements and calculations of the quantity and amount of the several kinds of work, and also that his classification of the material contained in excavations, shall be 'final and conclusive,' is a valid provision, and is binding upon the parties to the agreement. Therefore there can be no recovery in excess of the engineer's final estimate, unless such estimate is successfully assailed for fraud, gross errors, or mistake. * * *

"(*a*) The court will relieve against mistakes in measurements and calculations that are apparent on the face of the estimate, or that are clearly proven, though not so apparent.

"(*b*) If it is satisfactorily shown that the engineers failed, through oversight, to measure or estimate any particular part of the work, the court will grant relief as to such mistakes.

"(*c*) If it appears that the engineer in charge put a wrong construction on any provision of the contract, the court will correct any substantial errors resulting from such mistake, for the reason that the parties did not make the decision of the engineer as to the proper interpretation of the contract final and conclusive. * * *"

The Michigan Av. M. E. Church *v.* Wm. Hearson *et al.*, 41 Ill., Ap. 89.

"* * * The clause in the contract referring to the matter makes the architect's decision final and binding on both parties 'as to the interpretation of the drawings and specifications, and as to the quality or quantity of work or materials, or any other matter connected with the work, furnishing materials, or in settlement of this contract.' * * * Whether, under such a contract the contractors would be entitled to damages from the owner for delay which operated to greatly increase the cost of performing the contract, is a question not submitted to the architect by the terms of the clause of the contract above quoted. The claim for damages is based upon the alleged breach of an implied term of the contract,

and is not a matter necessarily connected with the work or furnishing materials, or other matters within the architect's province. Where an enumeration of specific matters is followed in a contract by general words or phrases, the latter are held to refer to the same kind of things or matters as those specified. 63 N. H., 166; 16 Blatch, 190. * * *"

Anderson *v.* Imhoff, 51 N. W. Rep., 855, Supreme Court of Neb., March 30, 1892.

"* * * The court did not err in overruling the motion. The reply does set up the ground of fraud, viz: 'That said decision was by said architect fraudulently and collusively made, * * *; and plaintiff says that said pretended decision was made in the absence of this plaintiff, and without any notice to him of the time and place when the same would be made, and that said architect refused to figure up the amount of said extra work and material in the presence of this plaintiff, or explain to this plaintiff the basis of his said pretended decision, but fraudulently and collusively refused to make the proper allowance for the material actually furnished and the work actually done by this plaintiff.' * * * The reply did not set up a new cause of action, but merely matter which, if true, would avoid the provision in the contract in regard to the adjustment and certificate of the architect. * * *

"The contract contains the following provision: 'And it is further agreed between the aforesaid parties that all alterations of the plans for this building by which the cost of building may be either increased or diminished shall be adjusted by the architect, whose decision shall be final and conclusive between the parties.' In effect the parties agreed that, in case extras were required, the architect should be the arbitrator to determine the compensation for such changes. Such an agreement, when carried out in good faith, is binding upon the parties. If, however, the arbitrator so chosen should refuse to perform the duties required of him, or should collude with either of the parties, and thereby render an unjust award, the adverse party would not be bound by a decision so rendered. * * *

"Any failure of an architect to consider all matters submitted

to him is to that extent a fraud upon the party discriminated against. * * *"

Williams *v.* Chicago S. F. & C. R'y Co., 20 S. W. Rep., 637.

"* * * The stipulation in the contract that the engineer's estimate and classification should be final is valid and binding, and has the sanction of the courts in England and the different States of the Union and the Federal courts. * * *

"* * * By such a stipulation the parties constitute the engineer an arbitrator, and the provision is held, if anything, more binding than an ordinary submission, for the reason that it enters into and becomes a part of the consideration of the contract, without which it would not in all probability have been made. It had its origin in contracts for the building of important and extensive Government works, and was designed to avoid harrassing litigation over questions that can only be determined honestly by those possessed of scientific knowledge. * * *"

Smith *v.* Morse, 9 Wallace, 76.

"* * * The law implies an agreement to abide by the result of an arbitration from the fact of submission. * * *"

Harvey *v.* U. S., 113 U. S., 245.

"* * * In regard to the view adopted by the Court of Claims, that the claimants have no right to rely on the testimony of experts introduced by them, but should have kept and produced accounts of the cost and expense of the work, we are of opinion that the claimants cannot be deprived of reasonable compensation for the work they did because the evidence they produce as to the proper amount of such compensation is not of the character referred to, when it does not appear that such evidence ever existed. If they produce the best evidence which is accessible to them, and it enables the court to arrive at a proper conclusion, that is sufficient. We think that such evidence is found in the estimate made by Mr. Abbott. * * *"

Court of Claims, vol. 15, p. 216.

"* * * This sum is composed in part of the damages sustained by the claimants from the refusal of the Government to permit them to complete their contract within the period fixed by its terms. The Government interposed unceasing delays from

the date of its execution in January, 1872, until May, 1873. Then the entire suspension of the work was required, and the changes in the original plan finally determined on.

"The claimants had a right to the full performance of the contract on the part of the Government. This right they have neither waived or forfeited. They have been deprived, through no fault of theirs, of the profits they might reasonably have expected to realize, and which the Government also must have contemplated they would make, at the time the contract was formed. The measure of damages in the case of a contract thus radically violated is settled by law. The party should recover his gains prevented, as well as his losses sustained. * * *"

110 U. S., 344.

"* * * So far as appears, they were incurred in the fair endeavor to perform the contract which he assumed. If they were foolishly or unreasonably incurred, the Government should have proven this fact. It will not be presumed. The court finds that his expenditures were reasonable. The claimant might also have recovered the profits of the contract if he had proven that any direct, as distinguished from speculative, profits would have been realized. But this he failed to do; and the court below very properly restricted its award of damages to his actual expenditures and losses. * * *

"But when he elects to go for damages for the breach of the contract, the first and most obvious damage to be shown is the amount which he has been induced to expend on the faith of the contract, including a fair allowance for his own time and services. If he chooses to go further, and claims for the loss of anticipated profits, he may do so, subject to the rules of law as to the character of profits which may be thus claimed. It does not lie, however, in the mouth of the party who has voluntarily and wrongfully put an end to the contract to say that the party injured has not been damaged at least to the amount of what he has been induced fairly and in good faith to lay out and expend (including his own services). * * *"

Court of Claims, Vol. 9, p. 253, Hardy *v.* U. S.

"* * * II. This brings us to the consideration of the rule

by which the damages are to be measured. Few cases exactly similar to this in all their features have been found in the books, but the principle on which the damages are to be estimated is abundantly recognized.

"At the common law, the principle is to give a compensation which shall put the injured party in the same position in which he would have stood had he not been injured. And in modern times, says Parsons on Contracts, edition 1866, vol. 1, p. 190, 'courts seek to apply to each case such rules as will carry out the universal principle, as far as may be, that the actual damages must measure the compensation given for it by law.' The Supreme Court, following this principle in the case of P. W. & B. R. R. *v.* Howard (13 How., p. 344), after declaring that actual damages include the direct and actual loss sustained, conclude their opinion by saying: 'We hold it to be a clear rule, that the gain or profit of which the contractor was deprived by the refusal of the company to allow him to proceed with and complete the work was a proper subject of damages.' * * * The readiness and ability of the claimant to perform, in this case, is equivalent to actual performance; and in such cases the measure of damages is *prima facie* the contract price; but circumstances may be shown which will mitigate the damages. Here no attempt has been made to excuse the default of the defendants or to mitigate the damages, and we can but give the rule its full effect. * * *"

94 U. S., p. 217, U. S. *v.* Smith.

"* * * In Clark's case, 6 Wall., 546, it was decided that the United States were liable for damages resulting from an improper interference with the work of a contractor; and in Smoot's case, 15 Wall., 47, that the principles which govern inquiries as to the conduct of individuals, in respect to their contracts, are equally applicable where the United States are a party. The same rules were applied in the case of the Amoskeag Co., 17 Wall., 592. Here the work was stopped by order of the United States. Smith asked to be released from his contract, unless he could go on. This was refused until the expiration of sixty days, when he was allowed to resume. As between individuals, certainly, this would be considered an improper interference, and damages

would be awarded to the extent of the loss which was the necessary consequence of the suspension. The United States must answer according to the same rule. * * *"

Court of Claims, vol. 25, p. 510, Bitting *v.* U. S.

" * * * It appears by finding III that the claimants lost twenty-seven working days in the months of May, June, and July, 1879, for lack of materials which the defendants were bound to furnish. It was necessary to retain, under pay, during this time certain employees, in order to proceed with the work as fast as the materials arrived. In this way the claimants sustained a loss amounting to $1,111. Inasmuch as this loss was caused by the failure of the defendants to perform their part of the contract, it should, in the opinion of the court, be borne by them. * * *"

Court of Claims, vol. 14, p. 234.

" * * * Undoubtedly, if the claimants had not accepted payment for the extra work and had brought their action, these things would have formed elements of damage when the court came to determine the amount of its judgment. But they cannot be set up separately or regarded as anything more than a part of the cost of the things paid for. The things sued for are delay, insurance, rent, interest, and profits, things which enter into every business and form elements of cost in every article bought and sold. In ordinary cases they are rarely a subject of consideration, and they came to the surface here only because the magnitude of this case is such that they are in a measure tangible from their extraordinary dimensions."

OIL FUEL EXPERIMENTS ON HYDRAULIC LIFE BOAT *QUEEN*.

By John Platt, Esq., Associate.

[Paper read at Annual Meeting.]

A series of experiments having been made burning both coal and oil in a Thornycroft boiler in the new hydraulic life boat *Queen*, built by Messrs. John I. Thornycroft & Co. for the Royal National Life Boat Institution, it was thought that a general description of the boat and the results of the experiment would be of interest to the members of the American Society of Naval Engineers.

The general question of hydraulic propulsion has been dealt with by Mr. S. W. Barnaby in a paper before the Institution of Civil Engineers (Minutes of Proceedings Inst. C. E., Vol. 77, p. 1). He also describes a previous hydraulic life boat, the *President Van Heel*, in the Proceedings Inst. C. E., Vol. 130, Part IV.

The vessel was designed by Mr. G. L. Watson, the naval architect to the Royal National Life Boat Institution, who furnished drawings and a specification, the builders, Messrs. John I. Thornycroft & Co., being responsible for the design of the machinery and for the attainment of a speed of 8½ knots.

The particulars of the vessel, which is named the *Queen*, are:

Length over all, feet	55
Length on water line, feet	53
Breadth, molded, feet and inches	13–6
Breadth over sponsons, feet	15
Breadth, extreme, over belting, feet	16
Depth, molded, feet and inches	5–6
Draught, extreme, feet and inches	3–6
Displacement, tons	31.10

The hull is of galvanized mild steel, having a tensile strength of 58,390 to 67,200 pounds per square inch and an elongation of

20 per cent. in 8 inches. The plating weighs between $7\frac{1}{2}$ pounds and $4\frac{1}{2}$ pounds per square foot. The seams are double riveted and the butt laps are treble riveted in way of engine and boiler rooms and double riveted elsewhere.

The hull is closely subdivided and the bulkheads are intact, the only water-tight doors being in the coal bunker bulkheads. Access is obtained to the small compartments for the purpose of examination and painting by manholes jointed with red lead in the bulkheads above the water line.

Longitudinal wing bulkheads extend for a length of 25 feet 6 inches on each side, enclosing the machinery space. They are 2 feet 6 inches from the side at the height of the water line amidship. They considerably reduce the volume of the machinery compartments, which are unavoidably long, and afford security in case of injury to the boat's sides. The wing compartments are subdivided by athwartship bulkheads, and on each side of the boiler room one of the compartments thus joined is used as a coal bunker.

Two strong side protective keels of American rock elm are fitted between angle bars, the bolts going through the flanges of the bars and not through the bottom plating. These are placed under the longitudinal side bulkheads, and are an effective protection to the pump inlet and to the bottom.

In the stern is the open cockpit, capable of holding about forty-five people. The deck of the cockpit is above the water and water tight. It is provided with the usual freeing valves to allow of the rapid exit of the water in case of a sea being shipped.

The rudder projects below the bottom of the boat in the usual life boat fashion. The rudderhead is hexagonal in section for a length of about 2 feet, and can slide up and down in a quadrant, into which is geared a worm spindle, which carries the storing wheel at its inboard end. The rudder can rise if it strikes the bottom, or can be triced up with tackle provided for the purpose without disconnecting the steering gear.

In the matter of steering the hydraulic life boat has a decided advantage. The engines and the centrifugal pump, which forms the propeller, naturally always turn one way, and reversing is

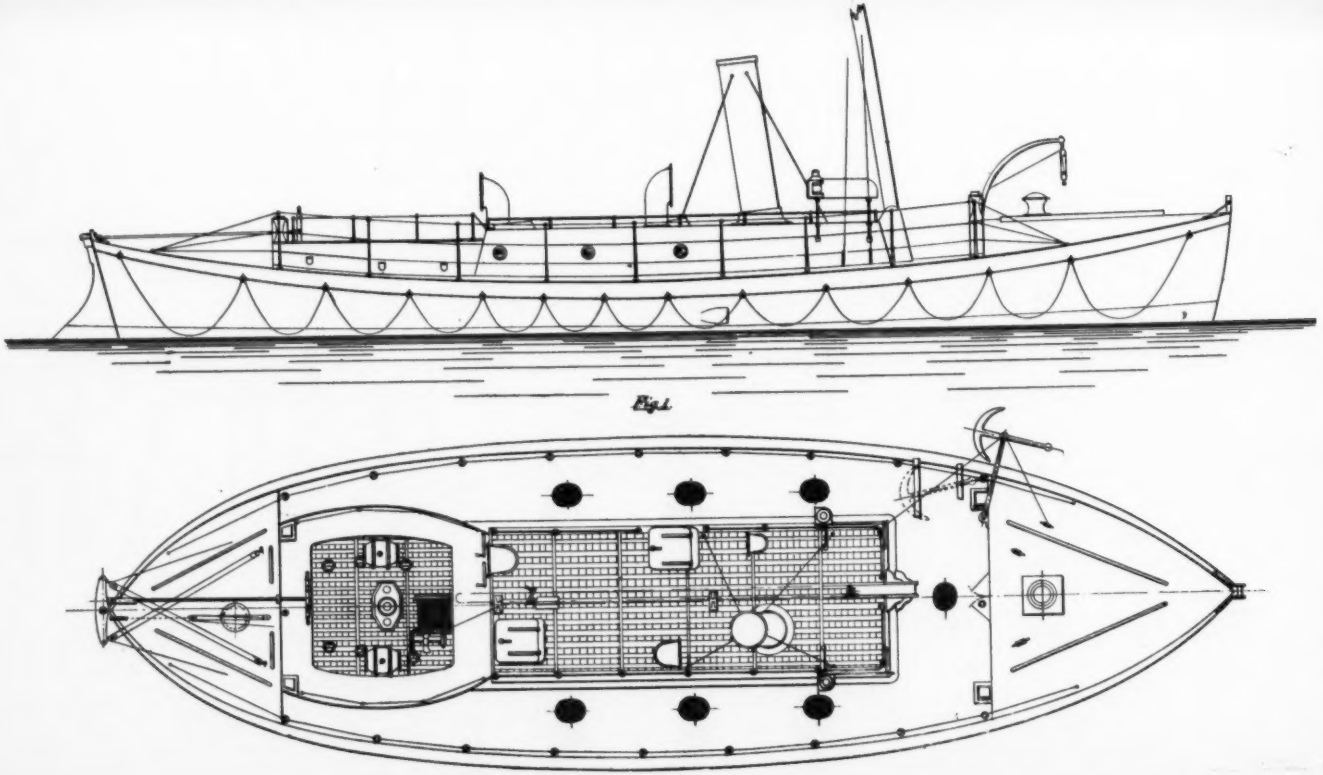


Fig. 1.

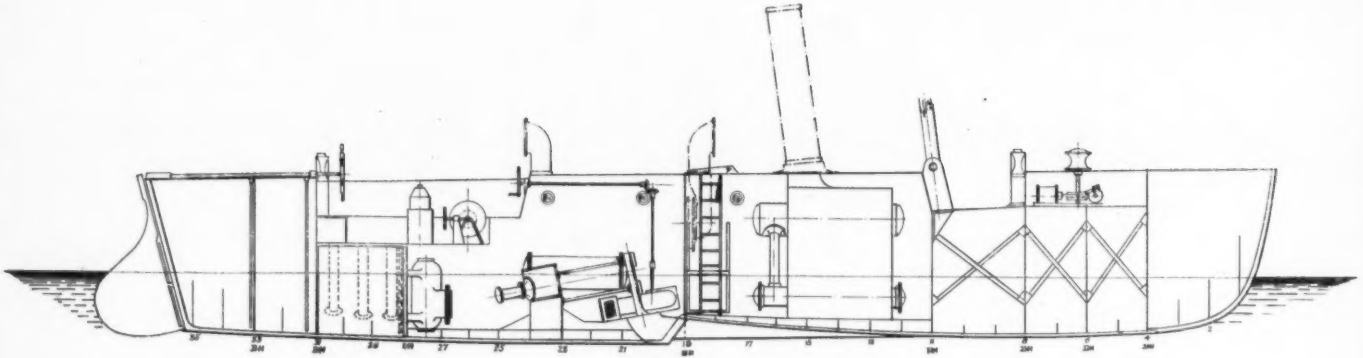
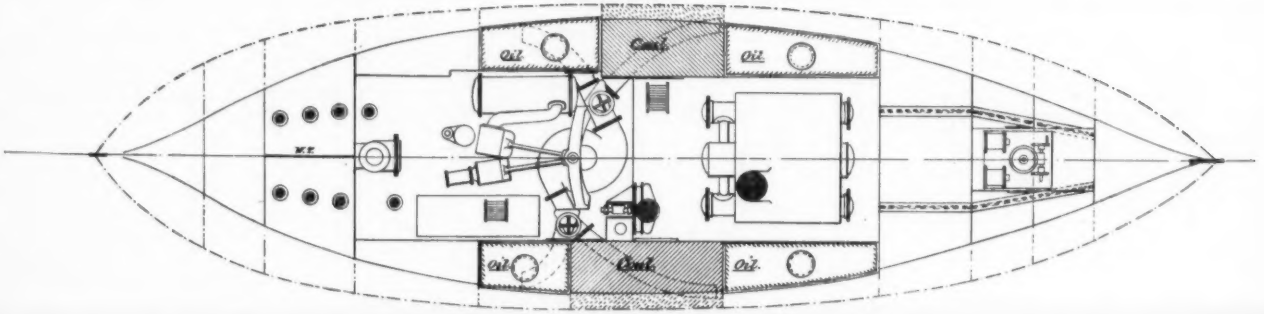
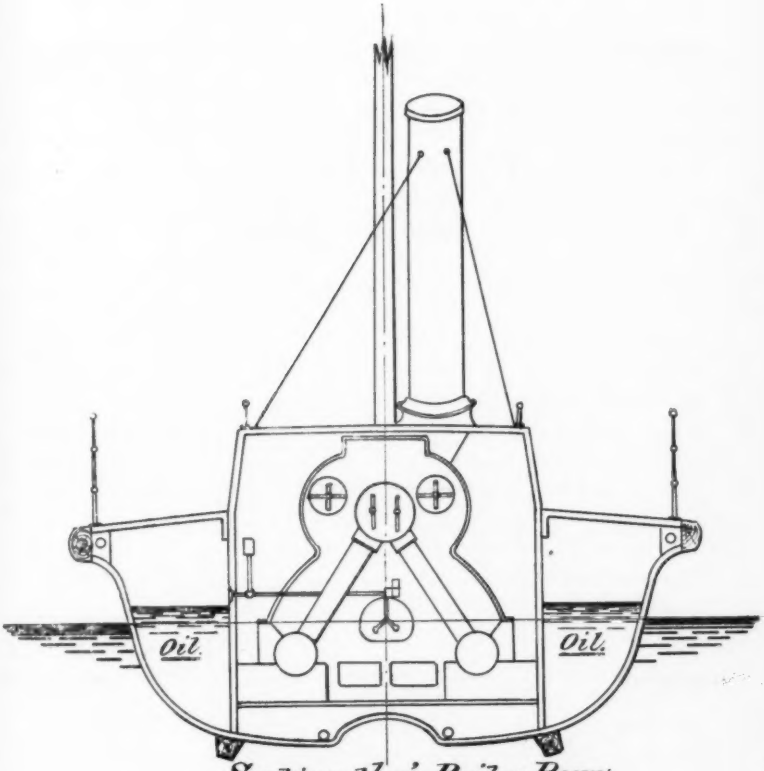


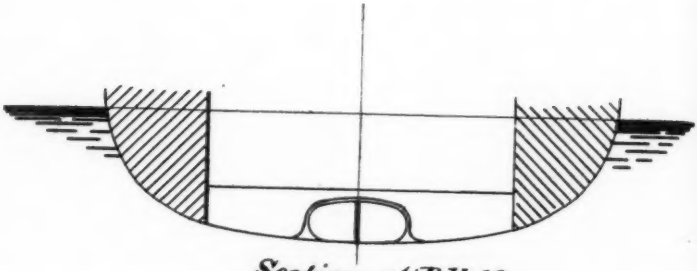
Fig. 3.





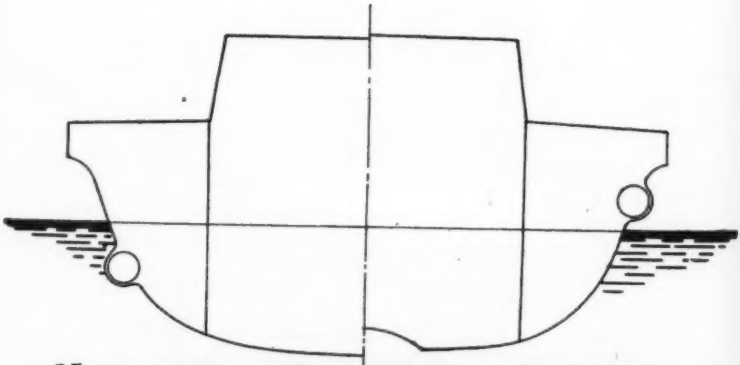
Section thro' Boiler Room.

Fig. 5.



Section at B.H. 12
showing Inlet.

Fig. 4.



Half section at Fr. 22.
showing Ahead outlet.

Half section at Fr. 16
showing "Astern" outlet.

Fig. 6.

effected by directing the flow of water either ahead or astern. The vessel is very easily managed by means of the jets.

At the forward end of the vessel upon the air casing is a steam capstan, and a steel wire rope hawser is coiled on a reel in the cockpit. A wire rope nipper is placed upon the engine casing, and an arrangement is provided for cutting the hawser in case of need. There are two sails, a dipping lug and a fore-stay sail. The mast can be hinged down upon the top of the boiler casing.

A double compound, surface condensing, inclined engine is used, having cylinders 8½ inches and 14½ inches in diameter by 12-inch stroke. The cylinders are inclined and actuate a single crank on a nearly vertical shaft. The air and bilge pumps and the two feed pumps are driven from the main engine. An independent engine and circulating pump supplies water to the condenser. The usual auxiliary feed pump is placed in the boiler room.

The main turbine and casing are of bronze, zinc protectors being provided to prevent galvanic action between pump and the shell of the boat, should the zinc coating of the latter be worn off. The inlet pipe and discharge pipes are of naval brass. The diameter of the turbine is 2 feet 6 inches, and at a speed of 9 knots the discharge is about 2,240 pounds of water per second. The nozzles are 9 inches in diameter. These nozzles are carried well forward and aft, as shown in Fig. 3. The distributing or reversing valves are placed at the junction of the ahead and astern discharge pipe. The nozzles for propelling astern are above water and are protected by the belting. Figs. 4 and 6 are sections through the inlet and ahead and astern outlets, and Fig. 5 gives a section through the boiler room. Fig. 7 shows diagrammatically one of the reversing valves. These are bronze castings bolted to the pump casings. They are square in cross section and the valve *V*, which is pivoted at *P*, moves from side to side and directs the water into the ahead or astern pipes as desired. When placed in mid position, dividing the stream, the boat stands stationary. The design of the inlet is such that the water is conveyed to the pump without shock, and the cross section immersed areas of the hull in way of the inlet are so formed as

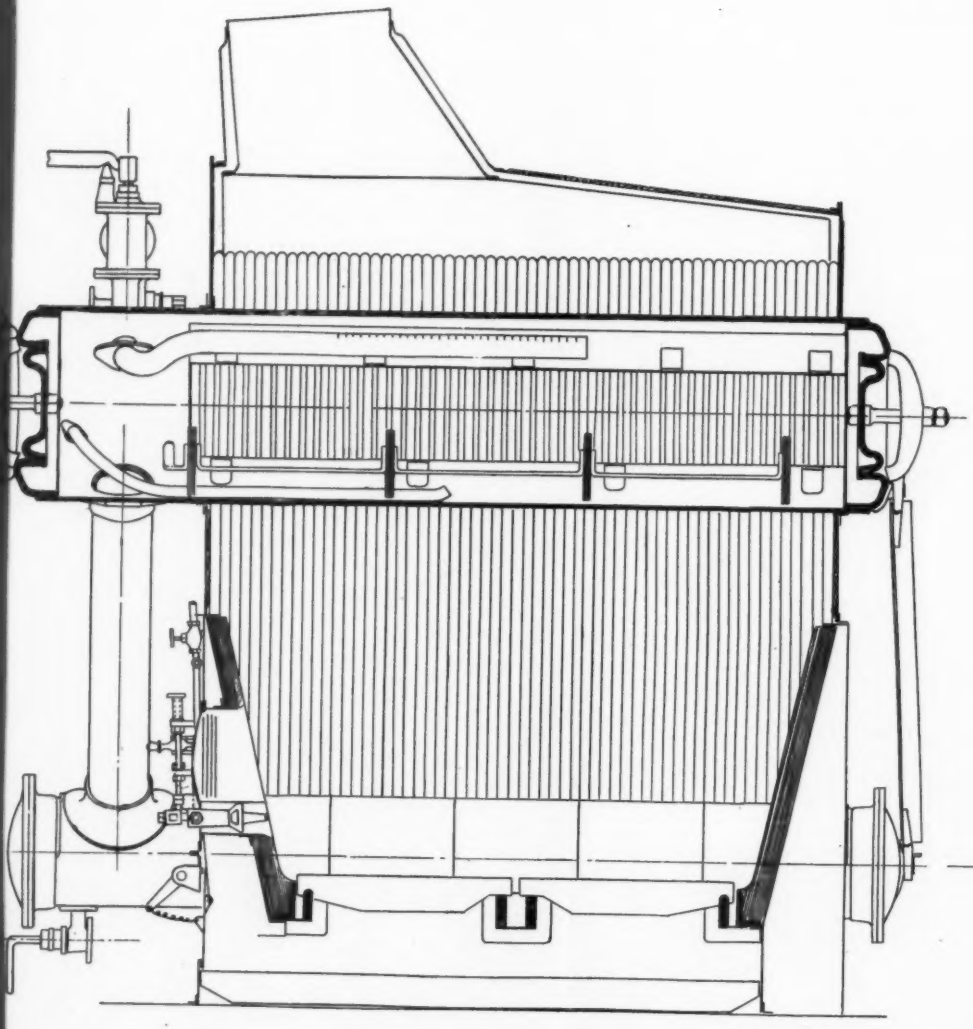
to allow the water to enter the pump without disturbing the natural flow of the stream lines.

The weights of the vessel are:

	Tons of 2,240 pounds.
Hull,	11.50
Fittings,	1.74
Woodwork,	1.68
Propelling machinery, and water in boiler condenser, turbine and pipes,	9.36
Engineer's stores,	0.33
Boatswain's stores,	0.30
Fuel, crew, passengers and reserve feed,	6.19
Total,	31.10

The metacentric height with all weights and a full load of passengers is 2.04 feet. Fig. 8 is the curve of stability under these conditions.

A series of trials was run with the *President Van Heel* to measure the I.H.P. required to drive the vessel at different speeds. The results are shown in Figure 9. The boat was brought to a draught of water corresponding with a displacement of 30.08 tons. It will be seen from the I.H.P. curve that up to a speed of 6½ knots the performance is fairly economical, but after this speed the curve rises rapidly. The guaranteed speed of 8.5 knots was obtained with 123 I.H.P., the engines working at half power. With 246 I.H.P. the speed was 9.29 knots. Much power is wasted by a hydraulic propeller when driven far above its designed speed. This, together with the fact that the length and form of the boat were not adapted for speeds above 8.5 knots, accounts for the extremely rapid rise of the power curve, which appears to be almost asymptotical to a speed of 10 knots, that is to say, it would not seem possible to obtain that speed however fast the turbine might be driven. The object of providing such a large reserve of power in the boat was not that she might be driven at a greater speed than 8.5 knots, but to ensure that the power wanted for this speed might be obtained without difficulty under the arduous conditions of the service.



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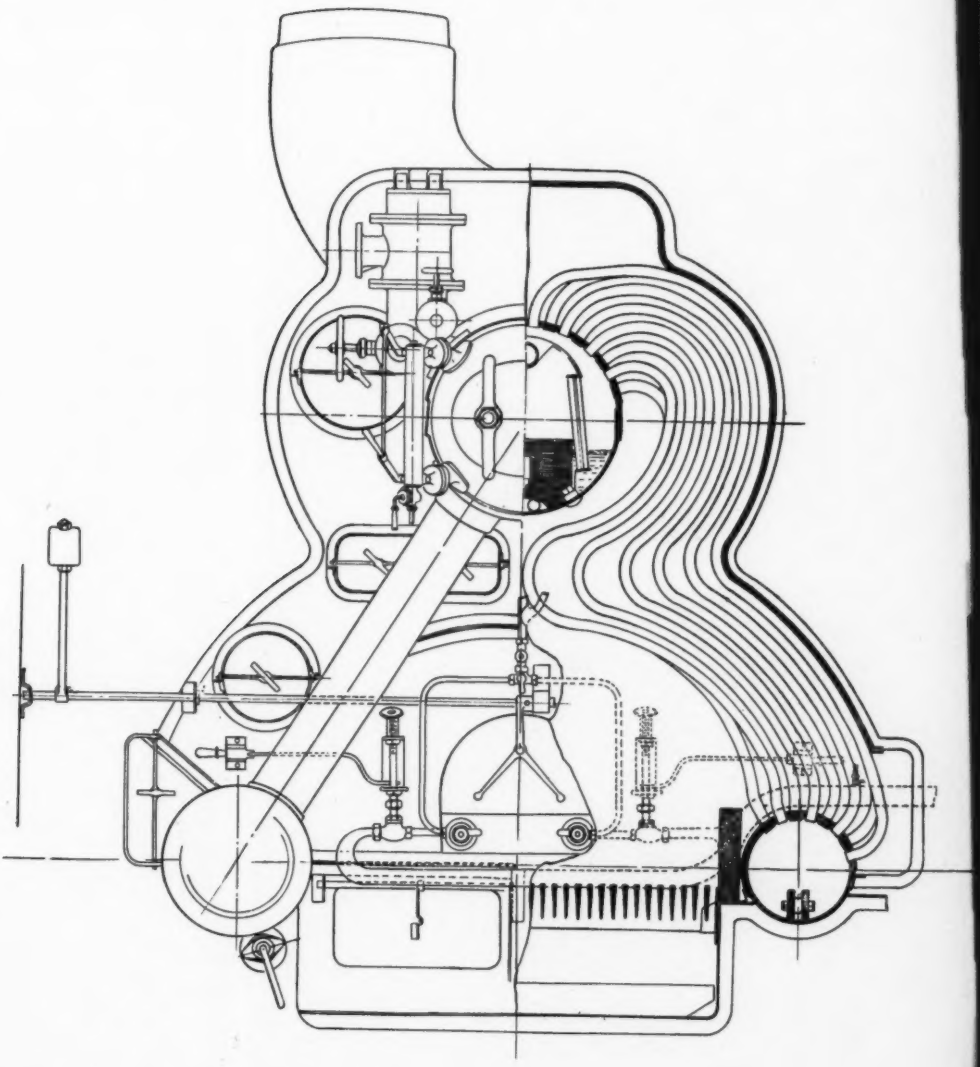


HORNYCROFT BOILER

A Thornycroft water-tube boiler of the "Speedy" type, is fitted in the boat. The effective heating surface is 610 square feet, and the grate area is 11.4 square feet. The steam pressure is 150 pounds per square inch and the test pressure 300 pounds. The drums are of Siemens-Martin steel $\frac{5}{16}$ inch thick, increased to $\frac{9}{16}$ inch thick at the tube plates. The tubes are of solid drawn steel, 1 inch external diameter, No. 14 B.W.G. thick. It was found that the boiler did not prime, although the movements of a vessel of this class are very violent when running in a sea way. Steam can be raised from cold water in 20 minutes.

The boiler was fitted for burning both coal and oil fuel. It was first fitted with two "Holden" oil burners operated by steam, the arrangement being that shown in the figure. A $1\frac{3}{4}$-inch bore oil-fuel main runs across the front of the boiler below the ash pit doors, and a $\frac{3}{4}$-inch bore pipe is led up from this on either side to connect with the burners. A $\frac{3}{8}$-inch bore steam pipe is led to each burner. The results given must not be taken as an exposition of the "Holden" oil burning system, the contractors simply using this particular burner to make their experiments.

A great number of trials were made without taking measurements of fuel, etc., as it was necessary to make a number of preliminary trials with each of the different positions of burners before the boiler could be made to work without making excessive smoke, which seems to depend on the relative position of the burner to the air admitted into the fire box, and whether it is admitted above or below the fire bars. Where the oil is burned in conjunction with the coal it is found that, if the greater part of the air is admitted above the fire bars, a smaller proportion of the coal will be burned, and there will be a greater tendency to smoke. On the other hand, by admitting a large proportion under the fire bars, the whole is more rapidly burned and the consequent higher temperature causes a better combustion of the oil and there is less tendency to smoke formation. Under these conditions a humming vibration is often set up which vibrates the boiler casing and is objectionable.

A series of tests were made with the furnace covered in with a

TRIALS OF THE THORNYCROFT BOILER FOR HYDRAULIC LIFE BOAT *QUEEN*.

		Oil trials.					Coal trials.		
Number of trial	1	2	3	4	5	6	1	2	3
Duration	65 min.	1¼ hours.	30 min.	30 min.	45 min.	45 min.	2 hours.	1 hour.	2¼ hours.
Atmospheric pressure, inches mercury	29.5	29.63	...	...	...	29.62	29.61	29.98	29.84
Air pressure in funnel, inches water	1.26	1.35	1.4	...	1.97	2.42	1.65	1.52	2.13
Air pressure in uptake, inches water	0.95	1.3	...	...	1.6	2.04	1.04	1.36	2.01
Boiler pressure, pounds per square inch	140	142.	153.75	152.5	160	156.0	158	128.4	162.3
Temperature of air, degrees Fahrenheit	55.3	59.3	55.7	55.0	56.6	59.0	57.4	53.7	59.8
Temperature of feed water, degrees Fahrenheit	51.2	51.5	50.5	50.0	51.3	51.0	50.22	52.2	56.4
Temperature of oil, degrees Fahrenheit	109.3	153.1	150.8	97	88.75	61.1	...	...	...
Temperature of casing, front, degrees Fahrenheit	145.4	...	...	...	...	...	152.7	129.6	107.1
Temperature of casing, side, degrees Fahrenheit	87.0	...	...	...	...	...	89.3	68.4	100.8
Temperature of casing, back, degrees Fahrenheit	132.6	...	...	...	...	...	134.8	129.8	128.6
Temperature in uptake, degrees Fahrenheit	729	693.3	710	703.3	781.2	671	787	728	787
Factor of evaporation	1.213	1.219	1.215	1.217	1.216	1.217	1.217	1.21	1.21
Total oil consumed, pounds	412.8	443	101.43	111.39	222.5	175	...	...	...
Oil consumed per hour, pounds	381	354.4	202.86	222.78	296.6	233.3	...	...	...
Oil per hour per square foot of grate, pounds	33.4	31.1	17.7	19.5	26.01	22.2	...	...	...
Coal consumed with oil, pounds	129.9	196	84	112	76.5	141.0	...	...	...
Total coal consumed, pounds	...	...	...	...	...	...	1,289	536	1,182
Coal consumed per hour, pounds	120	157	168	224	102.0	188	644.5	536	524
Coal per hour per square foot of grate, pounds	...	...	...	...	...	...	56.55	51.0	50
Total water evaporated, pounds	4,920	4,095	1,840	1,660	2,975	3,065	7,495	3,650	9,905
Total water evaporated per hour, pounds	4,560	3,276	3,680	3,320	3,966.6	4,086.8	4,747.5	3,650	4,400
Total water evaporated per hour from and at 212° F., pounds	5,531.28	3,993.4	4,471.2	4,040.4	4,823.3	4,980	5,770	4,420	5,320
Water evaporated by coal, pounds	957.41	1,442	619	825.4	563.8	1,039	...	...	...
Water evaporated by oil, pounds	3,962.5	2,653	1,221	834.56	2,411.2	2,026	...	...	...
Water per pound of oil, pounds	9.5	5.98	12.03	7.4	10.83	11.56	...	...	...
Water per pound of oil from and at 212° Fahrenheit, pounds	11.52	7.29	14.60	9.0	13.17	14.07	...	...	...
Water per pound of coal, pounds	...	...	...	...	...	...	7.37	6.82	8.4
Water per pound of coal from and at 212° Fahrenheit, pounds	...	...	...	..	...	...	8.97	8.25	10.17
Water per hour per square foot effective heating surface, pounds	7.47	5.37	6.03	5.44	6.5	6.72	7.46	5.98	7.22
Water per hour per square foot of grate, pounds	400	287.3	322.8	291.2	347.9	389 5	399	348	419
Horse power, (water per hour, 20)	228	163 8	184.0	166.0	198.33	204.38	237.38	182.5	220
Grate area, square feet	11.4	11.4	11.4	11.4	11.4	11.4	11.4	10.5	10.5
Effective heating surface, square feet	610	610	610	610	610	610	610	610	610

brick arch, which, when it reached a white heat, effectually prevented smoke and gave the best result. It was found that the large mass of brick took a long time to get heated through, which made the boiler so much slower at raising steam.

Trials were also made with the fire bars covered with pieces of broken brick, a small part being kept clear to light up with coal, which was also covered with brick when steam had been raised and the boiler heated up. It was, however, found impossible to keep the oil burners going without the addition of some coal.

After completing the preliminary trials it was found that under the conditions necessary in this boat, one burner was sufficient when placed quite close to the surface of the coal.

The table on previous page gives the particulars of both the coal and oil trials when measurements were taken.

The boiler was steamed where finished in the yard without any special setting up. The feed water was pumped in with duplex pump, the water being measured in tanks. The steam was blown off through the main stop valve. The draft was produced, or in the case of the oil fuel assisted, by a steam jet in funnel.

Oil Trial.—The coal used was Nixon steam navigation coal; on trials Nos. 1, 2 and 3 Astatki (flash point 310 degrees Fahrenheit) was used as liquid fuel, being heated by a steam coil to make it more fluid. On trials 4, 5 and 6 Wells oil (flash point 195 degrees Fahrenheit) was used, not being heated before being injected into the furnace. The liquid fluid was brought into the furnace by "Holden" jets, steam being used for injecting the oil. In trial 1, two burners were used, being placed well apart; on trials 2, 3 and 4, one burner was used, placed in the center; on trials 5 and 6, two burners, placed together in the center, slightly diverging and pointing upwards, were used. On trial 6, a brick arch 4½ inches thick, had been built into the furnace, and with a clearance of 2 inches between it and the water-tube arch. There were in the brick arch forty-five holes, 3 inches by 2½ inches, giving a flue area of 338 square inches. This arch reduced the grate area from 11.4 square feet to 10.5 square feet.

The water evaporated by the coal in the oil trials was calcu-

lated for an evaporation of 7.37 pounds of water per pound of coal, as found from the first coal trial.

Coal Trials.—Nixon steam navigation coal was used on the coal trials. On trials 2 and 3 the brick arch, as described under oil trials, was used, but not, however, in trial 1.

The author gives the particulars of these trials, simply as a result of some experiments made, to find out the best and simplest means of using oil as an auxiliary on a life boat. The results must not be taken as those that can be obtained by the use of the Holden burner, as this would not be at all fair to that system; nor must they be taken as giving the maximum amount that can be evaporated using oil under such a boiler.

The author is indebted to the builders of the boat, Messrs. J. I. Thornycroft & Co., for the particulars of the trials, and for the drawings of the boiler and the boat. Also to Mr. Sydney W. Barnaby, M. Inst. C. E., for the general description of the boat.

AMERICAN STEAM YACHTS.

By Irving Cox, Esq., Associate.

[Paper presented at Annual Meeting.]

Our steam yacht fleet is growing apace, and each year sees the addition of numerous vessels.

Two unpleasant facts, however, stare the investigator in the face, and it would seem that before much further progress is made the conditions leading to these facts must be altered, if not entirely removed.

First and foremost, during the last five years steam yachts costing over three millions of dollars have been built abroad for American owners, or, to put it more strongly, more money has been spent abroad by Americans for yachts than in the whole of the United States during the same time.

Secondly, we have no published or even unpublished records of trial trips—no way of comparing economy of coal per horse power developed, proportion of horse power to tons displacement and speed obtained—in fact, nothing useful to the naval architect or engineer in the way of performance data are to be had.

In respect to the first evil, we have at present an existing law which has checked, if not stopped, the actual building or buying of vessels abroad, but the law cannot change the conditions which led to the placing of orders abroad rather than at home, and these disadvantages must be removed by the combined efforts of the owner, designer and builder.

The greater first cost is the most serious obstacle in the way, and, as this is in a measure caused by the difference in price of labor, it is a difficult one to remove. Still much can be done by system and the use of labor saving appliances, so that with an

increased output we can probably come within five per cent. of the first cost of an English built boat.

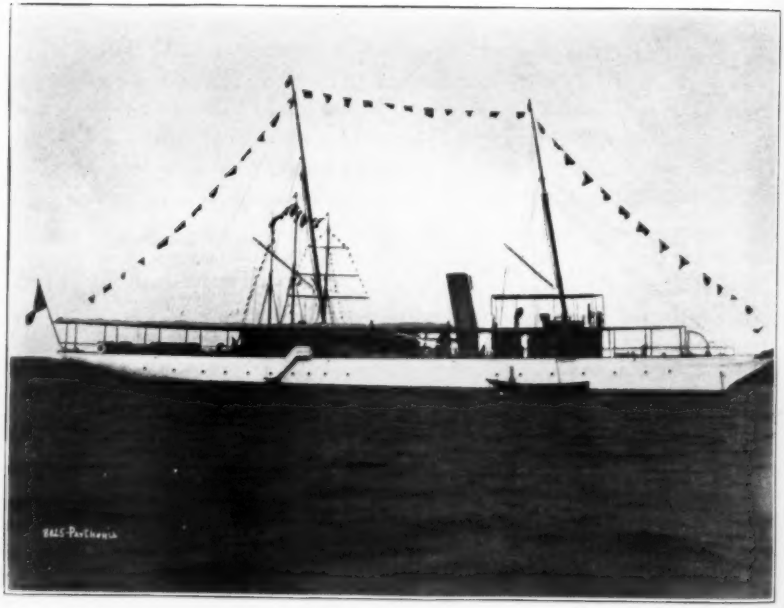
Mr. Charles Cramp is quoted as saying that English prices can be met with the same grade of work turned out; that the ordinary vessel of commerce is more carefully built and finished here than abroad, and to that the extra cost is due.

In comparing English and American steam yachts of the same apparent size, we almost always find nearly double the power in the American boats, and consequently double the machinery cost. In boats of 100 feet to 150 feet the English yachtsman is content with from 10 to 12 knots actual speed, while the required speed on this side of the water is from 14 to 17 knots for the same size boat. This extra speed is required for the service in which many of our yachts are employed, which is a daily run to and from the owner's place of business and his country home. Men like J. Pierpont Morgan, H. M. Flagler, E. C. Benedict, M. C. D. Borden, E. W. Ladew, F. J. Bourne and many others get almost all their yachting in this way. For such use speed is very necessary, and displacement must be light in order to secure it, making a very difficult problem to carry the motive plant and a sufficient quantity of coal for ordinary cruising.

The same conditions that led to the development of the shoal centerboard sailing yacht exert a marked influence on the steam yachts built in this country. We have from Maine to Florida a network of shoal but navigable inland waterways, affording a most attractive cruising ground to vessels of light draught but not suited to yachts of the English type.

The Government showed by sending the *Cushing* to Florida by the inside route what could be done with a light draught vessel, but 8 feet is the extreme limit, for many of the bars and shoals have a charted depth of less.

Abroad the conditions are absolutely dissimilar, as all the cruising is open sea work and draught of water no limitation. It is impossible to class and compare the two types on simply a basis of steaming radius and steadiness at sea, just as it would be unfair to condemn the deep draught yacht because of inability to enter many of the ports along our coast; yet the building of



"PARTHENIA."

steam yachts abroad has been caused quite as much by the mistaken idea that it was the only way to be sure of able and seaworthy vessels as by the difference in first cost. This idea has taken growth, as the writer has endeavored to show, by comparing boats built for different services.

The large sea-going steam yachts that have been built in America are *Eleanor*, *Sagamore*, *Nourmahal* and *Atalanta*, and all are able sea boats and comfortable cruising vessels, but the advancement in steam yacht construction has been so rapid that it is unfair to compare these boats with Watson's latest productions, *Varuna*, *Marguerita*, *Mayflower* and *Nahma*.

The total absence of data regarding the performance of existing steam yachts makes it impossible for the writer to give anything more than a brief resumé of some of the boats built by his firm, with a few cuts in illustration.

The *Parthenia* is a flush-decked steel steam yacht, designed in 1896 by our firm for Mr. Roach. She is a good example of the American type of yacht. Her length over all is 142 feet; length on water line, 115 feet; beam, 18 feet; and draught, 7 feet 6 inches; tonnage, 142.

Parthenia has a speed of 17 knots, burns 50 pounds of coal per knot at full speed, developing 550 I.H.P. She has six staterooms for owner and guests aft, and accommodations for a crew of sixteen men forward. Her joiner work is similar to that of all our boats, being soft wood, painted with enamel paint, except, of course, the interior of the two deck houses, which are of polished mahogany. Above the forward deck house is a bridge, where the hand steering gear is located. She is lighted by electricity, heated by steam, and has hot and cold water service in bathrooms.

Main Engine.—The main engine is of the vertical, inverted, direct-acting, triple-expansion type. It is arranged with the H.P. cylinder forward, I.P. cylinder aft, and L.P. cylinder in the middle, the cranks being 120° apart and following in the order named—H.P., I.P. and L.P.—the cranks turning to starboard from the top center. The cylinders are lagged on top and sides with asbestos and cased with Russia iron. The H.P. and I.P. cylin-

ders have each one and the L.P. cylinder two piston valves. The valve gear is of the Stephenson link motion, with double-bar links. The engine was designed to develop 550 H.P. when running at 320 revolutions, with a steam pressure of 225 pounds per square inch in the boilers. The cylinders are supported by wrought-steel columns, diagonally braced and resting on the bed plate. The guides for the crosshead slippers are of cast iron and are secured to the cylinders on top and to a longitudinal guide bar and columns on bottom. The crank shaft is hollow and in one section, of wrought steel. The air, circulating and feed pumps are all independent. The steam reversing cylinder is attached to bed plate. The following are some of the principal dimensions:

Number of cylinders	3
Diameter of cylinder, inches, H.P.	9
Diameter of cylinder, inches, I.P.	16
Diameter of cylinder, inches, L.P.	25
Stroke, inches	16
Diameter of H.P. valve, inches	6½
Diameter of I.P. valve, inches	10½
Diameter of L.P. valves, inches, (two)	10
Diameter of piston rods, inches	2
Length of connecting rods, center to center, inches	38
Ratio of net areas of pistons H.P. to I.P.	3.16
Ratio of net areas of pistons I.P. to L.P.	2.44
Ratio of net areas of pistons H.P. to L.P.	7.71
Crank shaft, length, feet and inches	8–5
Crank shaft, diameter, inches	5
Length of each crank pin, inches	8
Axial hole diameter, inches	3
Propeller shaft length, feet and inches	35–3
Thrust shaft length, feet and inches	9–8
Thrust shaft diameter, inches	5
Number of thrust collars	6
Thickness of thrust collars, inches	1½
Diameter of thrust collars, inches	10
Area of thrust surface, square inches	353

Propeller.—The propeller is right-handed, has three blades, and is of manganese bronze.

Number of blades	3
Diameter, feet and inches	6– 3
Diameter of hub, inches	18

Thickness of blades at root, inches	2⅛
Helicoidal area, square feet	13.25
Disc area, square feet	30.67
Pitch, feet and inches	7–6
Top of propeller immersed, inches	10

Condenser.—The condenser shell is cylindrical, of cast iron, with bronze tube plates and ends. It is placed on the port side of the engine room and firmly secured to floors and frames of hull. The circulating water passes through the tubes.

Number of tubes	663
Length between tube sheets, feet and inches	6–0
Diameter of tubes, inch	⅝
Cooling surface, square feet	650
Ratio of cooling surface to H.S.	1 : 2 3

Circulating Pump.—The circulating water is supplied by one centrifugal pump, the diameter of runner being 20 inches and of the suction and discharge pipes 6½ inches.

Air Pump.—There is one Hall vertical, duplex, vacuum pump, the diameter of water cylinders being 8 inches, the steam cylinder 6 inches and the stroke 8 inches.

Feed and Auxiliary Pumps.—There is one main feed pump and one auxiliary feed and bilge pump, both of the Worthington Admiralty pattern, the water cylinders being 3 inches diameter, the steam cylinder 4½ inches diameter, the stroke 4 inches.

Forced Draft.—The forced draft is supplied by a 42-inch fan, drawing air from the boiler room and delivering it in an air duct leading to the ash pits. The fan is driven by a single-cylinder engine, the diameter of which is 6 inches and stroke 3 inches.

Electric Plant.—The electric outfit consists of a General Electric, direct-connected dynamo and engine, of 100 16-candle power light capacity, located in the engine room. The dynamo, which is of the quadrupolar type, is driven by a double cylinder, vertical, inverted engine connected directly to the armature shaft. The diameter of the cylinders is 4 inches and the stroke 4 inches.

Boilers.—There are two Almy water-tube boilers, placed alongside of each other in a water-tight fire room. They are fitted with double front and closed ash pit for forced draft. The boilers are so connected that they can be used together or

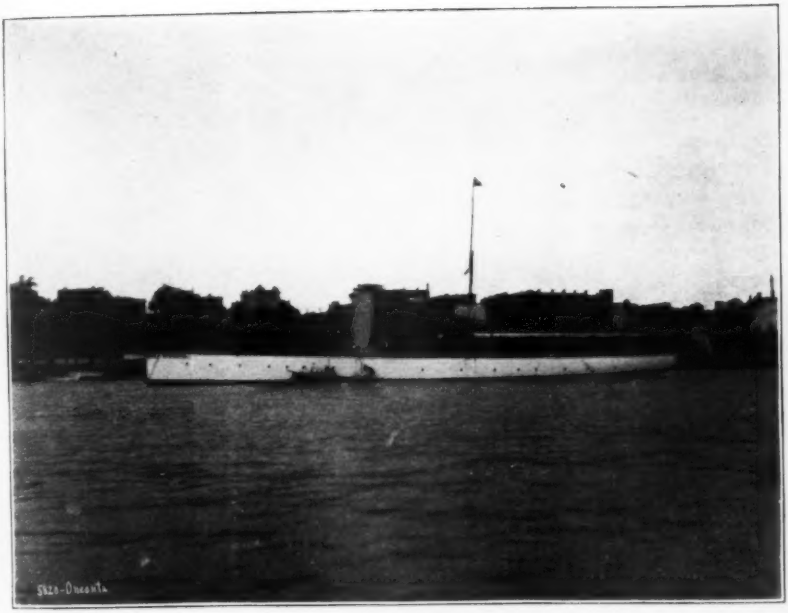
worked independently. The grate surface for each boiler is 21 square feet and the heating surface 750 square feet, making a total for both boilers of 42 square feet of grate and 1,500 square feet of heating surface. The working pressure allowed is 250 pounds per square inch. The outside dimensions over both boilers being 9 feet 8 inches by 6 feet 7 inches, and the total weight with water, including all fittings, being 24,500 pounds.

The *Oneonta*, built by Roach from our design, is quite different from the ordinary steam yacht in appearance. Length over all, 138 feet; 18 feet beam, and draws 8 feet of water.

She was designed primarily as a pleasure yacht, but the design was so made as to permit of her conversion into a torpedo dispatch boat.

In locating deck houses and placing of hull weights this conversion was borne in mind, and the designs were made to provide for the location of torpedo tubes, rapid-fire guns, protected conning tower and raised turtle-back deck forward. Thus the boat, in case of sudden war, could be converted in a very few days into a useful coast-defense boat. The *Oneonta* has made 100 miles over a measured course in 5 hours and 4 minutes. She is finished below in white and gold, with ladies' room of rose pink, and upholstery to match, and is very roomy for her dimensions.

The main engine is an inverted direct-acting triple-expansion engine, with cylinders 15, 23, 35 inches in diameter and a common stroke of 16 inches. The H.P. and I.P. cylinders are fitted with piston valves, and the L.P. cylinder has a double-ported slide valve. All valves are worked by the Stephenson link motion, with double-bar links. The cut-off for each valve is adjustable by means of slots in the reversing arms. The reversing gear is of the direct-acting type, and consists of a cylinder bolted to bed plate and connected to reverse shaft by double arms. The diameter of cylinder is 6 inches and the stroke $7\frac{1}{2}$ inches. The air pump is worked off the I.P. crosshead and is fastened to bed plate. Diameter of pump barrel is 16 inches and stroke 4 inches. In other respects the style of engine resembles very much *Parthenia's*, as described above.



"ONEONTA."

The surface condenser is oval in form and is of composition. The circulating water passes through the tubes and is supplied by a centrifugal pump driven by a single-cylinder engine, the size of which is 6 inches diameter of cylinder, and stroke 3 inches.

The feed, bilge and fire pumps are all of the Worthington Admiralty pattern, two of which are fitted in engine room and one in fire room. There is one 42-inch fan driven by a 6-inch by 3-inch single-cylinder engine, supplying the forced draft to boiler. It draws the air from the fire room and forces it through an air duct to boiler.

A General Electric dynamo and engine, of 100 16-candle power light capacity, is installed in engine room.

Boiler.—There is one Thornycroft steam generator, built under a royalty. Following are some of the principal dimensions:

Working pressure, pounds per square inch	250
Length over all, feet and inches	11– 0
Width over all, feet and inches	11– 0
Number of furnaces	2
Length of grate, feet and inches	8– 0
Width of grate, feet and inches	3–10
Grate surface, square feet	62
Steam drum, length over heads, feet and inches	10– 6
Diameter inside, inches	32
Thickness of welded seams and heads, inch	$\frac{7}{8}$
Water drum, diameter welded heads and seams, inches	20
Thickness, inch	$\frac{5}{8}$
Diameter of tubes outside, inches	$1\frac{1}{8}$
Heating surface, square feet	2,320
Ratio H.S. to G.S.	35:5

ENGLISH STEEL STEAM YACHT *PENELOPE*.

Designed by G. L. Watson. Owned by H. E. Converse, Boston, Mass.

Penelope is a flush-plated, steel, brigantine-rigged steam yacht of 541 tons burden.

Length over all, feet	218
Length load water line, feet	185
Beam, feet and inches	27–6
Draught, feet	14

She has a very fine white-pine deck, absolutely free from knots and blemish; masts, bowsprit and yards of Oregon pine. She has five staterooms aft for guests and five forward, a dining saloon on deck to seat ten, and one below to seat twenty-five or thirty at a pinch. She has four boats—one naphtha launch 24, feet by 6 feet; one steam launch, 28 feet by 6 feet, with steeple quadruple expansion engine; one gig, 26 feet by 5 feet 6 inches; one dinghy, 16 feet by 5 feet.

She has three compensating binnacles, steam steerer worked from pilot house or bridge; automatic engine-room signals from bridge and also from pilot house.

Joiner work is good—all bright wood, mahogany and teak. Paneling is so made that it is taken down in sections, central panel of tapestry. All berths are large and comfortable, with polished open-work fronts; two bathrooms for guests, large, and with running hot or cold water. All staterooms have running fresh water from deck tank. Ten staterooms and one on deck for crew extra. Galley, all in white tiling, on deck, with place to put dumb-waiter to pantry below, if desired.

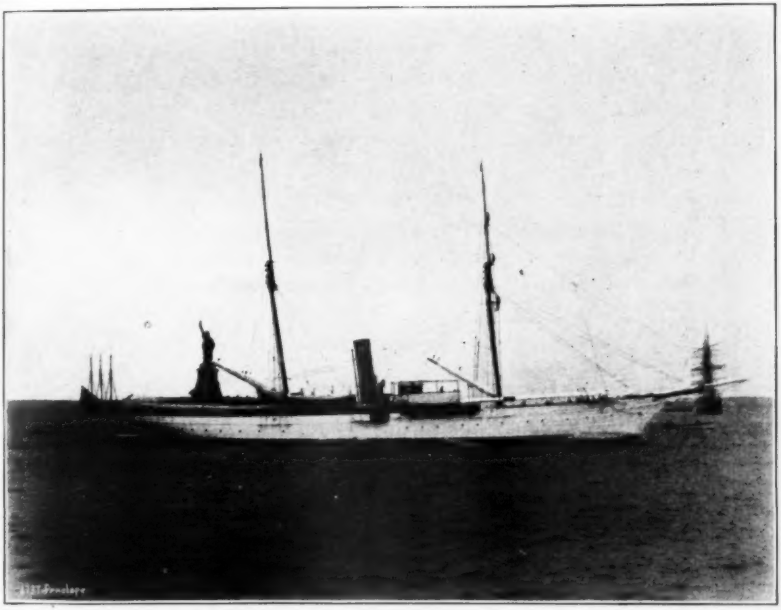
Accommodation for crew of thirty-six men all told; only carried thirty-two at sea. Has big lower hold for storage, with cold storage room, temperature 27°, holding 7,000 pounds of frozen meat. Has grocery room, wine cellar and big ice chest holding $2\frac{1}{2}$ tons of natural ice. Has fresh water tank of 4,000 gallons capacity; takes water about every two or three weeks in commission.

Maximum speed 13 knots and could be increased to 14 by addition of forced draft; one run being from Marblehead, leaving at 4.15 and arriving at New London at 7.25, an average of 13 knots.

Sea run from Bermuda to Old Point Comfort from 1 P. M. Saturday to 8.30 P. M. Monday, in very rough weather.

Coal capacity 186 long tons, radius of efficiency 4,800 miles. Freeboard at stem, 10 feet 2 inches; amidships, 5 feet; aft, 6 feet 5 inches.

Crew required.—Captain, 2 mates, 2 quartermasters, 10 deck hands, steward, assistant steward, cook, assistant cook, 1 waiter,



"PENELOPE."

2 mess boys, chief engineer, 2 assistant engineers, 3 firemen, 2 coal passers.

Wages, $1,400 per month; food, $16 per day. Costs to run, from $3,800 to $4,000, including ten guests.

Machinery and Boiler.—Triple-expansion three-cylinder engine, by Ramage & Ferguson. I.H.P., 750. Cylinders: high, 18 inches; intermediate, 29 inches; low pressure, 47 inches, by 33 inches stroke; 94 revolutions; steam pressure, 160 pounds. Engine carried on wrought columns front, columns cast with condenser back. High-pressure valves, pistons; intermediate and low, slide valves, taking steam on back of valve. Length of engine room, 16 feet 5 inches; height of engine, 14 feet. Thrust, of horseshoe type, 4 rings, Katzenstein metallic packing. Revolutions at sea, 86 to 90 per minute. Two wheels—one manganese bronze, one cast iron; diameter, 11 feet 6 inches; pitch, 15 feet 6 inches. Surface condenser cast in frame of engine, tubed with $\frac{5}{8}$-inch composition tubes ferruled into head. Vacuum, 26 to 27 inches. Air and feed pumps direct driven by arm from main engine, side by side. Has independent circulating pumps and auxiliary feed, also Hancock inspirator, all engine and boiler room tools, and work bench, revolution counters, etc. Crank-pins are solid, crank-shaft built up.

Bulkhead doors water tight and can be worked from above. Engine room large, light and cool when running. Evaporator fitted in engine room to supply waste in boiler supply.

Boiler, Scotch; return tubular type; built by Ramage & Ferguson. Diameter, 14 feet 6 inches; length, 11 feet 6 inches. Two double Morison ribbed furnaces, $7\frac{1}{2}$ feet by 45 inches diameter. Grate area, 67 square feet. Heating surface, 1872 square feet. Tubes, $3\frac{1}{2}$ inches outside diameter; number of tubes, 196.

Boiler is clean, tubes are tight and crown sheets and tube sheets seem in good condition. Athwartship bunker holds 80 tons; two side bunkers 53 tons each. Has ash ejector fitted with steam ram. Boiler casing, uptake and stack in good condition.

Electric light plant is 100-light capacity; King & Ronan make of dynamo, engine by Roby & Co. Speed, 350 revolutions.

Storage batteries are sufficient in capacity to run plant twenty hours without recharging. Fixtures in main cabin are all in good taste and wiring is all concealed.

De La Vergne ice machine, capacity, 150 pounds per day; will keep 8,000 pounds of meat in cold storage frozen at 27°, and cool room for vegetables at 42°.

The *Penelope*, as can be seen, is a very completely fitted craft, and reflects credit on her designers and builders, yet such a boat is far easier to build than the one with 3 knots more speed that would be demanded by a man intending to build on this side of the Atlantic.

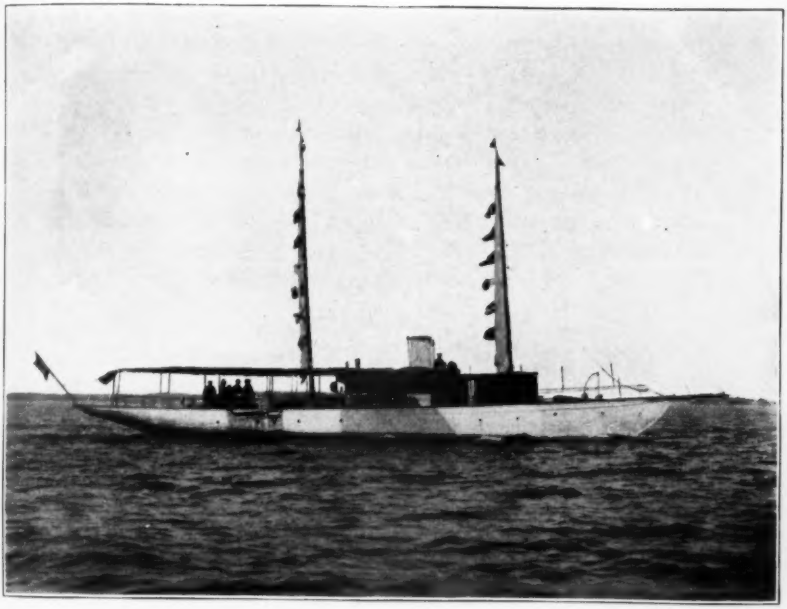
TIDE.

Tide is built of steel, is 93 feet over all, 72 feet on water line, 14 feet beam and draws 5 feet 6 inches. The dining saloon is in deck house forward, and will seat ten people, and contains buffet and lift from galley. The helmsman steers from a bridge aft of deck house. Below, forward, there is the galley, pantry, double stateroom for officers, and crew's quarters. Aft there is a double stateroom with two berths, main saloon with buffet, two comfortable staterooms forward of saloon, and lavatory.

The motive power consists of a three-cylinder, vertical, inverted, triple-expansion engine, with independent air and feed pump and surface condenser. The engine cylinders are 6 inches H.P., 10 inches I.P., and 16 inches L.P. by 10 inches stroke. They are arranged with the H.P. forward, the L.P. aft and intermediate pressure in the middle. The cylinders are all fitted with piston valves driven by the Marshall gear. The engine was designed to develop 150 H.P. when running at 340 revolutions, with 230 pounds of steam per square inch on the boilers. There is a surface condenser with 180 square feet of cooling surface. It consists of a steel shell with bronze tube plates and ends. The circulating water passes through the tubes and is supplied by a centrifugal pump driven by a 3-inch by 3-inch engine.

There are two Davidson vertical pumps for the feed, bilge and fire service, and one Hall vertical duplex vacuum pump.

The electric outfit consists of a Riker direct-connected dynamo



"TIDE."

and engine of forty 10-candle power light capacity, and a storage plant to run the lights when the dynamo is not running.

The forced draft is supplied by a 20-inch-diameter Sturtevant fan, driven by Halsey engine.

Boiler.—There are two Almy water-tube boilers, designed for a working pressure of 250 pounds per square inch. They are fitted with double front and closed ash pit for forced draft. They can be worked either separately or independently. The grate surface of both boilers is 20 square feet and the collective heating surface is 740 square feet.

The boats illustrated and described are, in their way, representative craft. That the writer has been unable to give more exact data no one regrets more than himself. A very interesting series of tests now being made by Professor Denton, of Stevens Institute, on the steam yacht *Sovereign*, will prove a valuable addition to existing information, and, had there been time, an effort would have been made to secure some of the figures.

ECONOMY OF ELECTRIC LAMPS.

By Chief Engineer G. W. Baird, U. S. N., Superintendent of State, War and Navy Department Building.

The quality of the incandescent lamp plays a very important part in the economy of an electric plant, and the competition between lamp manufacturers is now so sharp that it is essential to exercise a closer inspection. When lamps cost a dollar apiece the duration of the lamp was an important factor. Now that the price is about eighteen cents, the economy of the glow has advanced in importance. The brighter a lamp glows, with a given amount of current, the shorter will be its duration; conversely, a lamp which glows dimly will last for many months, but it will take more current per candle power. Formerly it was the custom to keep a lamp in use until it burned out; now we condemn a lamp which has lost about 25 per cent. of its candle power.

The relative economy is easily calculated. A 16-candle power lamp which will emit a candle power for 3.1 watts requires 49.6 watts per hour. Its duration is about 500 hours. The cost of the lamp is 18 cents. The cost of a 1,000-hours light would be $\left(\left[\frac{49.6 \times 500 \times 0.04}{1{,}000} + 18\right] \times 2\right) = \$2.34$, the cost of the current being 4 cents per 1,000 watts.

The cost of the same 16-candle power light for the same time, using a 4-watt lamp, which would glow twice as long, would be $\left(\frac{4 \times 16 \times 1{,}000 \times 0.04}{1{,}000} + 18\right) = \$2.74$. This is an apparent saving of nearly 14 per cent. in favor of the 3.1-watt lamp.

A 3.1-watt lamp at 112 volts will become a 4-watt lamp at about 100 volts, but its duration will be more than doubled. A 20-candle power lamp (112 volts) will become a 16-candle power lamp at about 105 volts pressure, and its lifetime more than doubled.

A dealer may place a 20-c.p. 112-volt lamp alongside a 16-c.p. lamp on a 105-volt circuit; it would glow equally as brightly and last nearly three times as long, which would be evidence of superiority to the average consumer. If, however, he kept a record of his coal expenditures, and made use of his record, he would discover that the increased cost in fuel exceeded the saving in the cost of lamps. This has been the experience of the writer, and, to protect the Government against loss, the writer has installed in this building a photometer, with a pair of volt meters, a watt meter and a rheostat, which enables him to test lamps from 70 up to 116 volts. Some of these tests afford surprising results; the more so when we realize that nearly all the lamp makers use the same "squirted" filament, from the same material, and made in the same manner excepting in the details of exhausting the lamp. Each one, of course, claims the best method; each salesman can produce records of tests proving his lamps the very best. Life is too short to question their facts or to decide their disputes; the records of our instruments alone determine whether or not a bill of lamps shall be accepted.

An officer from a public building recently sent me some lamps for test; they had been placed in his circuit and glowed so much brighter than his original lamps that he was favorably impressed. They were marked 16 c.p., 110 volts. They averaged from 19.6 to 23.3 c.p. at that voltage, and showed 2.9 watts per candle power. Here is exactly the condition referred to above, and indicates how readily we may be deceived.

Another lot of lamps, sent for test, were marked 20-c.p., 70 volts; they gave 20 c.p. at 68.5 volts at 3.2 watts per c.p.; the test was made by varying the voltage until the 20-candle power was reached. Another lot of lamps marked 16-c.p., 112 volts, averaged 16.055 candles, varying from 15 to 17.6, using a mean of 3.02 watts per candle power. A number of 20-c.p. lamps, 112 volts, showed a mean of 19.97 candles at 2.94 watts per candle power.

An old 20-c.p. "Edison" lamp, which had been glowing probably 1,000 hours, gave 15.44 c.p. at 68 watts, having lost nearly 23 per cent. of glow and required 4.36 per cent. more current.

Another old "Economic" 16-c.p. lamp, which had glowed about the same length of time, showed but 5 c.p. on 44.5 watts, being a loss of 68 per cent. in light and an increase of 120 per cent. in current per candle power.

Ten lamps were put in one circuit, which were operated by one switch, so that all must glow the same period. Five of these were of the Edison and five of another make. At the end of seven months, the lamps having glowed about 700 hours, three of the Edison and two of the others remained alive. The remaining live lamps, which were originally 16-c.p., 112-volt, 3.1-watt lamps, were then tested. The Edisons, at 112 volts, gave 10.97 c.p. and required 4 watts per candle power. The lamps of the other make emitted 8.9 c.p. and required 4.6 watts per candle power.

Three lamps from a new company were sent me for test. They were, as usual, warranted to be the best in all respects. They were marked 112 volts, 16 c.p. My test showed, at 112 volts, a mean of 12.66 c.p. and a consumption of 4.12 watts per candle power.

We received a bill of 100 lamps, 16 c.p., 112 volts, for our regular service. Four of them were "blown" the instant current was put on them. The remaining 96 averaged 13.28 c.p., requiring 3.52 watts per candle power. They varied from 8.5 to 18.8 candles power. They were rejected. Another 100 lamps from the same factory yielded 95, which glowed from 9.7 to 22, averaged 16.05 c.p. at 3.28 watts per candle power. Five of them "blew" upon the first flow of current. They were guaranteed to be 16-c.p., 3.1-watt lamps. The price was 17 cents each, or $34 for the 200. Deducting the 9 burnt-out lamps, the price would be $\left(\frac{34.00}{191}\right) = 17.8$ cents apiece. A later test of 44 lamps, 6-c.p., showed a variation from 6 to 9 candles power, and out of 100 4-c.p. lamps but 93 would glow (7 blew), which varied from 4 to 6 candles power, averaging 4.22 watts per candle power.

If a lamp maker use the same material for the manufacture of his filaments, uses the same die through which to "squirt" it, and is careful to cut the filaments exactly the same length, it

would appear reasonable that he would have a uniformity of output. I have no doubt they make a reasonable effort in that direction, but it is clear that their efforts are not successful. A better plan would be to test every lamp and mark the result of the test upon the base. The fact of so many lamps "blowing" upon the very first flow of current is evidence that they have never had full current upon them before. In testing some lamps I find they lose brilliancy quite rapidly at first; in a few seconds the spot on the photometer disc changes so that I have to move the carriage two or three centimeters to bring it to the normal. Such lamps, I thought, had never been glowed before.

The increased demand for light makes it imperative that economical lamps be used, to prevent, as far as possible, an overload. When the plant in this building was installed (1891), we had wired about 1,500 lamps in this building and about 900 in the Executive Mansion; the capacity of one plant is 80 kilowatts. We figured on a maximum load of 75 per cent., which was verified in practice. Since then the lamps have increased to about 3,100 in this building and about 960 in the Executive Mansion, besides which there are motors and fans to be driven.

There is difficulty in enforcing or inducing the average employé to observe economy in the use of the light; the lamp glows without any apparent consumption, such as would be so evident in a gas light, and they see no need of extinguishing lamps at all; the light is convenient and so cleanly, and the demand for an increase is constant. That it is the rival of gas light and not of daylight, seems to be forgotten. In this building there are about 6,000 gas jets, and the average number of jets in operation was 144, or less than $2\frac{1}{2}$ per cent. before the installation of the electric plant, while the average number of electric lamps now glowing in the building is 366.

During the working hours the load factor in per cent. of one plant averages from 33 to 42 per cent.; on dark days from 70 to 90 per cent, and on rare occasions we have had an overload. One man is detailed, at certain hours, to patrol the building and extinguish the electric lamps not in use; this has resulted

in a saving of from one-fourth to one and a fourth tons of coal per day.

A number of new gas burners, some resembling the Welsbach, have come to us for test, and are worthy of a place in this record. We have a fine Heilne & McIlhenny gas meter, which has been verified by displacement test, which we use in testing gas burners. The following is a record of the gas tests:

GAS TESTS.

Name of Burner.	Pressure in inches of water.	Feet of gas per hour.	Candles power.	
International Incandescent	1	3	28	Incandescent, similar to Welsbach.
Welsbach	1	2	29	Incandescent.
Richardson	1.1	2.2	32	Incandescent, similar to Welsbach.
Richardson	1	4	17.5	Lava tip, fish tail.
Ballard	1	6.3	23.3	
Ballard	1.1	1.35	0.8	Brass tip, pin hole, flame 4 in. high.
Ballard	1	5.3	22.4	Lava tip, fish tail.
Ballard	1	5	18.8	Iron tip fish tail.
Ballard	1	5.2	16	Brass tip, fish tail.
Beacon Co.	1	8	16	Two jets on one cock, fish tail.
Beacon Co.	1.1	5	21.1	Lava tip, two pin holes.
Acme	1.1	1.7	12	
Matchless	1	4.2	17.6	
Matchless	...	$\frac{1}{2}\frac{1}{0}$	...	Turned down to its stop.
Matchless	1.05	5.5	20.3	Two pin holes in a brass tip.
Argand	1	4.1	16.8	
Bray	1	4	12.1	

Fig. 2 SHOWING RESULTS OF EVAPORATION TESTS OF "YARROW" BOILER.

Note. The full line has reference to a "Yarrow" boiler with all tubes embraced in general circulation.

The dotted line has reference to same "Yarrow" boiler with 3 outer rows of tubes supplied direct from feed pump and consequently colder than under previous conditions.

NOVEL ARRANGEMENT OF FEED-WATER HEATER IN WATER-TUBE BOILERS.

[Description of some Experiments with a Water-Tube Boiler.*]

By A. F. Yarrow, Esq., Vice-President I. N. A.

In this paper, which I have the pleasure to submit to the meeting, I propose to describe some experiments made last year by us with one of our water-tube boilers. The boiler selected had a grate surface of 33 square feet and a heating surface of 1,840 square feet, having tubes varying from 1¼ inches to 1 inch in diameter.

Fig. 1 gives a general idea of the boiler, which, no doubt, is familiar to most of you. Numerous experiments were tried with a view to test the consumption of fuel at different rates of evaporation, and, to make comparison easy, the results were set out in the form of a curve, as shown in Fig. 2. The horizontal distances represent the amount of water evaporated per pound of Welsh coal and the vertical distances the amount of water evaporated per square foot of heating surface.

As the draft is forced and the evaporation more rapid, the extent to which the economy falls off is clearly seen. This mode of setting out boiler experiments renders comparison between different boilers and changes in the same boiler very apparent.

The various spots on the diagram represent different experiments, and the thick line *A B* shows the results obtained with the boiler as usually constructed. To the thick line is added a dotted line, *B C*, showing further results at abnormal rates of evaporation. In these experiments the feed was passed into the boiler, mixing at once, as usual, with the water already in the boiler. After making a large number of trials with the ordinary

* Paper read before the Institution of Naval Architects.

method of feeding, we then partitioned off, as shown in Fig. 3, by diaphragms in the bottom pockets, three outer rows of tubes on each side, and we allowed the feed water to pass in at the right-hand side of the diaphragm on the right-hand leg, and at the left-hand side of the diaphragm on the left-hand leg. The effect of this was to increase the evaporative efficiency, as indicated by curve *D E*.

The reason for the advantage gained a little reflection will show. Take, for example, a working pressure of 250 pounds. The corresponding temperature will be 406 degrees Fahrenheit. Assuming that the heated gases coming in contact with the last three rows of tubes have a temperature of, say, 700 degrees, there will be a difference of temperature between the heated gases and the tubes of 294 degrees Fahrenheit. Now, if those three rows of tubes are supplied direct from the feed pump with water, say, at a mean temperature of 200 degrees Fahrenheit, there will be a difference between the temperature of the water in those tubes and the gases coming in contact with them of 500 degrees Fahrenheit; *i. e.*, in the latter case the difference of temperature will approach nearly twice what it was in the former case, and, as the greater the difference of temperature between the gases and the heating surface the greater the absorption of heat, the advisability of keeping as cold as possible those surfaces which are called upon to absorb the last remnant of heat from the gases is clearly evident. The outer rows of tubes thus act, as it were, as an economizer or feed heater of a very simple character, forming part of the boiler proper, having the advantage that, instead of being in the uptake and depending for their supply of water solely on the feed pumps (which, in case of stoppage, might result in serious damage through the surfaces becoming overheated), in the system described the tubes are dependent upon two means of supply, namely: from the feed pumps, or (in the case of the stoppage of the feed pumps) from the water in the upper chamber, which would flow down into these tubes.

This remarkable gain we desired to have confirmed quite apart from our own observations and in an altogether different manner from that in which our experiments had been tried. Professor

Fig. 1.

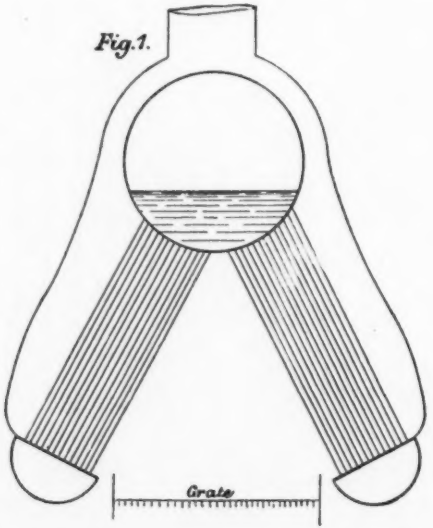


Fig. 3.

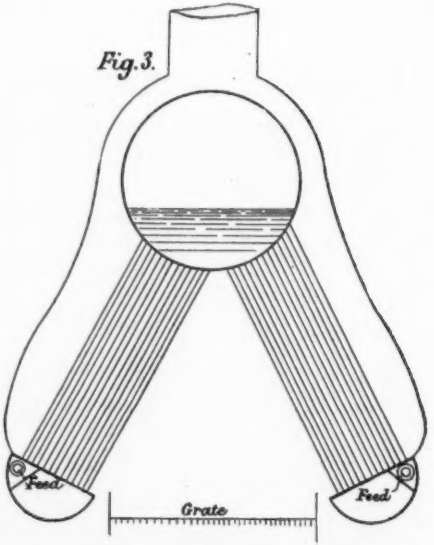


Fig. 4.

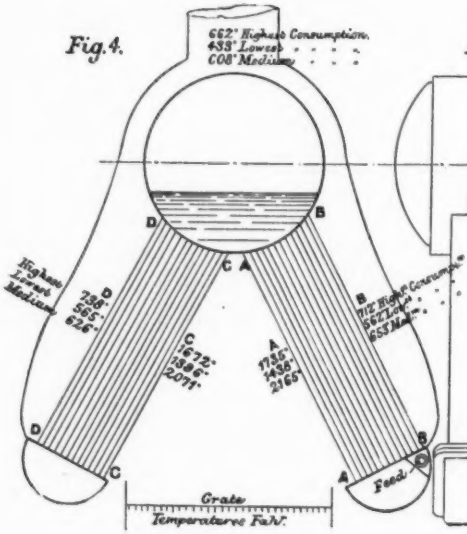
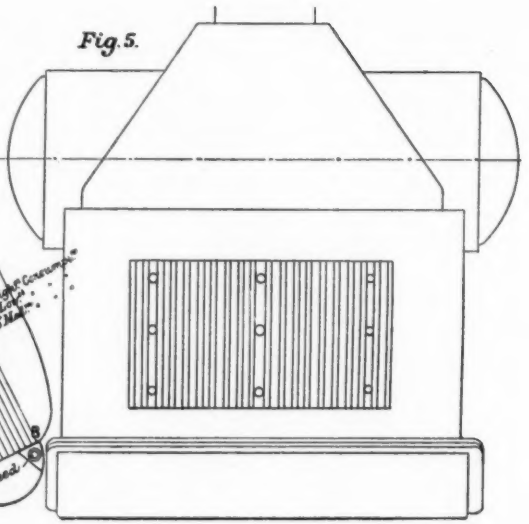

662° Highest Consumption.
433° Lowest . . . .
608° Medium . . . .
D
B
C
A
Highest
Lowest
Medium
D
738°
565°
626°
C
1672°
1386°
2091°
A
1736°
1438°
2165°
B
1112° Highest Consumption
564° Lowest
655° Medium
D
C
A
B
Feed
Grate
Temperatures FahT.

Fig. 5.



Lambert and Mr. Haddon, of the Royal Naval College, kindly undertook to investigate this for us. In order to test the comparative merits of the two systems, namely, (1) feeding by the ordinary method, and (2) by passing the feed water through the three outside rows of tubes before mingling with the water in the boiler, the latter plan was adopted on the one side of the boiler, and the former plan, in which all the tubes took part in the general circulation, carried out on the other side of the boiler, as shown in Fig. 4. The object in view was to ascertain the temperature of the gases immediately before they came in contact with the heating surfaces and their temperature immediately they left the heating surfaces, the difference indicating the amount of heat absorbed; and, clearly, if in one system more heat was absorbed than in another, other conditions remaining the same, that form of construction which led to the greatest absorption of heat would necessarily be the more economical.

I cannot do better than now give an extract from the report of Professor Lambert and Mr. Haddon:

Temperatures were measured by a Le Chatelier platinum and platinum-rhodium couple, combined with a "dead-beat" galvanometer, carefully calibrated. The wires from the couple were covered with asbestos thread, and cased in a 4-foot length of ½-inch gas pipe.

In the first and second trials observations were taken while the furnace doors were closed, 3 inches away from the tubes, at nine different points on each face of each group of tubes, as indicated in Fig. 5, holes having been cut in the boiler casing at the level of these points for the introduction of the tube containing the wires and couple.

In the first experiment a rapid rate of combustion (52 pounds per square foot of grate) was maintained. In the second, a low rate of combustion (19 pounds per square foot), and in this trial special care was taken to read off at each point, as nearly as possible, the same time after stoking, and always at that set of tubes further from the door (there were two fire doors) at which stoking had last taken place, in order to lessen the large irregularities due to periodical and frequent stoking. The means of the

temperatures on the four faces are indicated in the accompanying Fig. 4.

In order to further eliminate the irregularities due to the varying conditions of the fire, a third trial was undertaken, in which a very long series of observations was taken at about half-minute intervals, without reference to the times of stoking, so as more nearly to correspond to actual conditions, the temperatures being read off simultaneously by two thermo-couples fixed opposite the centers of faces *A* and *B*, and afterwards a similar long series of observations opposite the centers of *C* and *D*. In all, over 300 records were made. The means of the temperatures thus last obtained on the fire faces are higher than those of the first two trials, as all the records were taken at the middle faces, where the previous experiments had shown there was greatest activity. The results are recorded in Fig. 4 and in the following table.

Trial number.	Pressure in pounds per sq. inch.	Consumption per sq. foot of grate.	Feed side.		Other side.		Excess difference in favor of feed side.	Funnel temperature.
			Face A.	Face B.	Face C.	Face D.		
		Pounds.	*Deg. Fahr.*		*Deg. Fahr.*		*Deg. Fahr.*	*Deg. Fahr.*
I.	180	52	1735	712	1672	738	89	662
			Diff. = 1023		Diff. = 934			
II.	180	19	1438	562	1396	565	45	433
			Diff. = 876		Diff. = 831			
III.	180	31.4	2165	653	2071	626	67	608
			Diff. = 1512		Diff. = 1445			

Funnel Temperatures.—These were taken by the thermo-couple at the bottom of the funnel, 9 inches below the steam blast, while the doors were closed, and at different periods after stoking, and the means of several observations gave temperatures 662 degrees, 443 degrees and 608 degrees Fahrenheit, in the first, second and third trials respectively.

Analysis of Flue Gases.—During the first experiment three samples were taken from the bottom of the funnel by an aspirator, and submitted to quantitative analysis, with the following results:

	Percentages, volumes.			
	Carbonic acid.	Oxygen.	Carbonic oxide.	Nitrogen and water vapor.
Sample A. Doors closed. One minute after stoking	10.5	9.5	0	80
Sample B. One door open. Sample taken during stoking and after	9.03	12.0	0	78.97
Sample C. Doors closed. Immediately after stoking	14.33	5.53	0	80.14

The absence of carbonic oxide in each case indicates that the combustion was perfect.

Sample A showed that 54.8 per cent. of the total oxygen admitted had been utilized.

Sample B, with open door, showed, of course, a less proportion of oxygen utilized, viz: 45.5 per cent.

Sample C, taken with doors closed, and immediately after stoking, gave a higher proportion of oxygen utilized, or 73.1 per cent., apparently indicating, to a certain extent, a higher efficiency than when sample A was taken after the doors had been closed for one minute. The medium consumption (third) trial was confined to the middle of the faces of the tubes, where the fire temperatures were highest. The temperatures recorded are, therefore, higher than in the other two cases in which observations were taken also in less active places.

General Remarks.—The highest temperature recorded was 2,282 degrees Fahrenheit in the first trial. The difference between the mean temperatures on the inner and outer faces of the tubes was in each case greater on the side in which the outer rows of tubes only were supplied with water direct from the feed pump, the difference in favor of this system being 89 degrees in the experiment with rapid combustion, 45 degrees

Fahrenheit in the case of slow combustion, and 67 degrees in the medium case. These results clearly point consistently to the advantage of the new feed system and towards confirming the previous experiments, as indicated by curves $A\,B$ and $D\,E$, Fig. 2.

In connection with this subject, attention may be drawn to the fact that, whatever gain there may be by the system described in this paper, it will increase as the working pressures, and consequently the temperatures, of the water rise. During these experiments the varying efficiencies of different systems of stoking were most apparent. The object, of course, is to secure complete combustion and entire absence of carbonic oxide in the flue gases, and to secure this with a minimum admission of air, the heating of any excess of air representing loss in economy. There are devices for continuously recording, in the case of stationary boilers, the specific gravity of the flue gases, which serve to indicate if there be present carbonic oxide or unconsumed air, and I am told, on the best authority, in works where such a device is in daily use and the stoking guided by it, a marked economy has been the result. I would submit that if a device of this kind could be designed so as to render it applicable for use on board ship it would serve as a guide to efficient stoking.

Discussion.

Mr. C. H. Wingfield was the first speaker on this paper. He said that Mr. Yarrow was very much to be congratulated on the simple form of the feed heater which he had applied to his boiler and on the considerable improvement in evaporative duty which had, as might be expected, resulted from its adoption. He had for a long time been using a diagram similar to Mr. Yarrow's Fig. 2, except in regard to the curvature of the lines, and he wished to say a few words about these lines.

Mr. Wingfield's diagram was shown on the walls of the theater, and we give it on the opposite page. It would be seen, he said, that it was essentially a straight-line diagram. He had had considerable experience in plotting experimental results, and he always preferred, before making a diagram, if possible, to so arrange his data that, when plotted, they should theoretically lie

Fig. 2 $W_C = EB - (W_h \times A)$

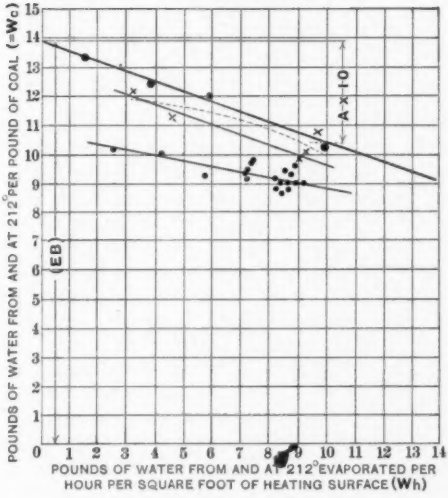
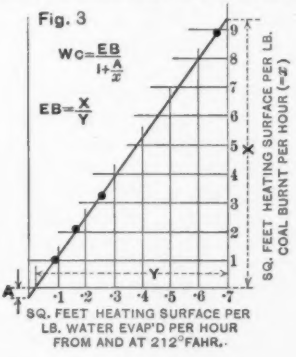

POUNDS OF WATER FROM AND AT 212° PER POUND OF COAL (=Wc)
(EB)
A × 10
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14
POUNDS OF WATER FROM AND AT 212° EVAPORATED PER HOUR PER SQUARE FOOT OF HEATING SURFACE (Wh)

Fig. 3


$W_C = \frac{EB}{1+\frac{A}{x}}$
$EB = \frac{X}{Y}$
SQ. FEET HEATING SURFACE PER LB. COAL BURNT PER HOUR (=x)
Y
A
·1 ·2 ·3 ·4 ·5 ·6 ·7
SQ. FEET HEATING SURFACE PER LB. WATER EVAP'D PER HOUR FROM AND AT 212° FAHR.

along a straight line. Professor Rankine had given an approximate equation on page 293 of his "Steam Engine" for determining the probable efficiency of a boiler, and from this Mr. Wingfield had, some eight years ago, derived the expressions shown on the cut, viz:

$$Wc = \frac{EB}{1 + \frac{A}{x}}$$

and $Wc = \{EB - (Wh \times A)\}$; where Wc = pounds of water evaporated from and at 212 degrees per pound of coal; Wh = pounds of water evaporated per hour from and at 212 degrees per square foot of heating surface; x = square feet of heating surface per pound of coal burnt per hour; E = theoretical evaporation from 1 pound of coal; B and A = constants depending chiefly on the design of boiler and the supply of air to the fuel, respectively.

It would be seen that $\{Wc = EB - (Wh \times A)\}$ was the equation to a straight line. To test the accuracy of this deduction he had plotted the four trials made by Professor Kennedy with a Thornycroft boiler of the *Speedy* type, and it would be seen how closely the four large dots lay along the thick straight line, thus amply confirming the accuracy of Rankine's methods. He had selected this particular series of trials on account of the extraordinary care taken by Dr. Kennedy to eliminate error as far as possible, but Messrs. Thornycroft had made other trials which also amply confirmed the corrections of Mr. Wingfield's straight-line diagram.

On the same diagram he had reproduced the dotted curve of Mr. Yarrow's Fig. 2, the experiments on which it was based being shown by the five crosses. Without the knowledge that the true equation corresponded to a straight line, this curve was probably as good as any other of the many lines which might have been drawn among the crosses. The moment it was known that a straight line might be expected, it was at once seen that the thin straight line the speaker had drawn was almost certainly the correct one; four out of the five crosses falling practically on it. This result is greatly to the credit of the officer conducting the trial. In the same way, a straight line fitted the experiments without a feed heater, at least as well as Mr. Yarrow's curve, and as it agreed with Rankine's equation, Mr. Wingfield's own diagram was, he thought, more likely to be correct.

It was obvious that, though so closely correct within the limits of the diagram (a trial with another boiler justified the extension of the thick line as far as shown), the curve could not be straight indefinitely, otherwise it would cut the base at some point at which, while the evaporation was very high per square foot of heating surface, no water was evaporated per pound of coal. This would be an obviously absurd result. No doubt the line would bend so as to become more and more nearly parallel with the base, to which it would approach more and more, but without ever reaching it. He thought the curves in Mr. Yarrow's Fig. 2, tending, as they did, to become less and less parallel to the base as the evaporation increased, must necessarily be inaccurate.

Since deducing the equations he had given, he had learnt that the one in Fig. 3 had been previously published on page 224 of Dr. Thurston's book on the steam boiler. As Rankine did not show how to obtain the values of his constants A and B, Mr. Wingfield had indicated two methods. In Fig. 2 the value of EB could be read off directly, and by dividing by E (the evaporative value of the coal) it was easy to obtain B. The slope of the straight line gave A, which was, of course, one-tenth of the "dip" on the tenth division. Mr. Wingfield preferred Fig. 3, however, for the purpose of determining the constants. In it the base represented heating surface per pound of water evaporated from and at 212 degrees, and above this he plotted corresponding values of the heating surface per pound of coal burnt per hour. A was obtained by direct measurement and the slope of the thick line, drawn through Dr. Kennedy's experiments, gave the value of EB.* The speaker thought it a pity that in some quarters the air pressure allowed in a stokehold was restricted, since it was not necessarily a measure of how hard a boiler was worked. The true measure of forcing was, as shown by the diagram, the rate of evaporation per square foot of surface, and higher air pressures would not improbably result in greater economy when combined with judicious design. The need of a good instrument for measuring the carbonic oxide in smoke was pointed out by Professor Unwin in his Forrest Lecture, and Mr. Wingfield hoped, with Mr. Yarrow, that the many inventors who were, he knew, at work on this problem would soon bring it to a satisfactory solution.

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* It may be interesting to point out that the form of Mr. Wingfield's diagrams, and of Professor Rankine's equations, follow from the fact that the flow of heat from gas to water in a boiler varies as the square of their difference in temperature. See "Engineering," vol. LX, page 50.

Sir John Durston wished to add his congratulations to those of Mr. Wingfield upon the very interesting paper which Mr. Yarrow had contributed, and he would take that opportunity of bearing witness to the great willingness which Mr. Yarrow had always shown to give to the Institution information obtained in his experimental work. The speaker had put on the wall of the theater a diagram prepared to show the results of certain evaporative trials made with the Belleville boilers of the *Sharpshooter* and the *Powerful*. He failed to see the double advantage which Mr. Yarrow claimed in regard to getting economy and also freedom from breakdown in case of the pumps giving out. He thought, if the feed were stopped, the boilers would soon come to grief. Mr. Macfarlane Gray had stated on the previous day that the efficiency of the boiler where feed heating was used was due to the greater capacity of the heating surface, and this was undoubtedly the fact. The coldest water should meet the coldest gases. It would be interesting if Mr. Yarrow would put one of this new type of boiler into a boat and thus get the combined efficiency of boiler and engine, so removing any question that might arise as to the quality of the steam. The temperatures of the fire that were given were very interesting. It would be seen that over 2,000 degrees was recorded. He would like to ask whether care was taken to eliminate the effect of radiation, and thus get only the temperature of the flowing gases. The record of these suggestions brought to his mind how good a thing it would be if a big laboratory could be started by means of which boiler and engine trials could be made on a large scale, results being obtained by means of a Froude's dynamometer.

Mr. Milton pointed out that Mr. Yarrow had not mentioned all the advantages that followed from putting feed into the boiler in the way described. He had dealt with evaporative efficiency, but there was one other point to which the speaker would call attention. If sufficient heating surface were allowed in the feed tubes, all deposit and impurities that might be in the water would be deposited in those tubes. They were furthest removed from the fire, and would be least likely to burn out, whilst clean surfaces would be obtained for tubes immediately in contact with the hottest gases and the radiant heat of the furnace. Sir John Durston had asked what would happen if the feed pumps stopped. Of course, if the feed pumps broke down altogether, and nothing were done to the fire, the boiler would be destroyed; but considering the question of feed stopping through slowing down or any circumstances of that nature, they might consider that

ordinary precautions would be taken as to shutting dampers, &c. In any case, however, these rows of tubes would only be in the same position as the rest of the boiler. Circulation would go on in this bit of the boiler just as it would do now in the whole of the ordinary boiler. Mr. Yarrow had shown by experiments that tubes furthest from the fire would act as down-comer tubes, and that would take place in the three back rows of the boilers illustrated, the water ascending in those nearer the fire. Sir John Durston had referred to the advantages gained with the Belleville boiler in regard to fuel economy in consequence of fitting economizers. But Mr. Milton would point out that there was another feature in these new boilers that had to be taken into consideration. This was the combustion chamber between the steam-generating elements and the economizer elements which distinguish this new form of boiler. The Belleville specially wanted a combustion chamber, particularly when working at high rates of evaporation. This was apparent from what Sir John Durston had said on the previous day when he had told the meeting that additional air was admitted under pressure between the two sets of elements. Other boilers had the disadvantage of the steam-generating tubes being so close to the fire, and an effort had been made to cure this by leaving out rows of tubes. To judge by the diagram, a gain of about 15 per cent. in economy had been obtained by putting in the economizer associated with the combustion chamber. Sir John Durston here stated the gain was from 15 to 22 per cent. Mr. Milton, continuing, said 15 per cent. was approximately the gain that Mr. Yarrow had made by his new arrangements, but the speaker was of opinion that the actual figures would show something a little less than this. In the paper it was stated that 67 degrees was the mean difference in one set of experiments, but it was curious that the mean for the figures obtained on the three sets of experiments, under varying conditions, was also 67. Mr. Yarrow had used 20 pounds to 21 pounds of air per pound of coal. By Rankine's method of finding the temperature of combustion, and taking the figures recorded showing the loss of temperature of the gases in passing among the tubes of the boilers, and further assuming that the loss of temperature would be proportional to the amount of heat absorbed, it would be found that rather less than 15 per cent. gain would be reached. A few years ago he was occupying his mind with a scheme for firing boilers. On comparing notes with his late friend Mr. Blechynden, it was found they had both been working on the same lines. Mr. Blechynden, in connection with this matter, gave him some re-

sults of experiments he had made with a Blechynden water-tube boiler, and these results agreed very closely with those obtained by Mr. Yarrow and shown on his diagram. Mr. Blechynden obtained an evaporative result of 9 pounds of water per square foot of heating surface, which was nearly the same figure as was given in one of Mr. Yarrow's experiments. At an evaporation of 6 pounds of water Mr. Blechynden's figures came still nearer those of Mr. Yarrow, but when the evaporation was reduced still further to 3 pounds the efficiency fell off and was absolutely less than was obtained when the 6 pounds of water were evaporated. The latter figure gave the maximum efficiency for Mr. Blechynden's boiler. This caused some surprise, and, in order to investigate the matter, sight holes were put in the sides of the boiler. In this way it was possible to follow the working of the furnace, and it was found that, with low rates of fuel consumption, the gases, instead of flowing so that they were spread over the whole area of heating surface, took the shortest cut to the chimney and left large parts of the tubes untouched; the whole heating surface was, therefore, not in practical operation. The incident showed that it would not do to go too much on theory, and Mr. Wingfield's formula was not everything that was required. He would suggest to Sir John Durston that it would be advantageous to put cold water into the top of the economizer instead of into the bottom. In that way the theory of hottest gases and hottest water would be carried out more fully; a simple mechanical arrangement could be fitted to prevent the economizer from emptying itself if the feed pumps stopped.

Mr. Rounthwaite asked why Mr. Yarrow put the feed water in at the bottom of the tubes instead of supplying it from the top vessel. As so arranged, it had to be discharged upwards, which was against the natural course of circulation; if the feed were put in at the top it would give an improved circulation, and he did not think there would be any great mechanical difficulty in effecting this.

Mr. Macfarlane Gray referred to remarks he had made on the previous day. He thought Mr. Yarrow would get a still better result than had been obtained if the feed water were supplied to the boiler at the temperature of the steam. It might be taken as a principle that no heat should be supplied to the boiler by the fire for the purpose of raising the temperature of the water; only latent heat should be communicated through the heating surface of the boiler. All other heat should be supplied by means of

steam from the boiler, which would heat up the cold feed until the steam temperature was reached, so that only the latent heat had to be supplied to make steam.

Mr. Hughes asked if it would not be advisable to connect the rows of tubes inside the vessels.

Mr. Haddon described at some length the methods followed by professor Lambert and himself, by means of which temperatures had been obtained. They had screened the thermo-junction so as to cut out the radiant heat of the furnace in some of the experiments, and had found practically the same result, whether the wires were subject to the radiant heat or not. In the thermo-couple, resistance increased with a rise of temperature. Not much was known of temperatures above 1,000 centigrade. One great difficulty was to insulate the wires of the junction upon each other, and for this material they had found asbestos thread answer best. The speaker then described the manner in which the pyrometer had been calibrated, the usual plan of employing the melting points of various substances having been followed.

Mr. Watt said many years ago he had made a water-tube boiler which had not only a feed-water heater, but had a feed-water casing as well. This was fitted in order to prevent heat getting to coal in the bunkers.

Mr. Yarrow, in replying to the discussion, said he agreed with Mr. Wingfield that it would be very nice if the curve on the diagram could be made into a straight line, but he thought it was fairer to make the line go over the spots than the spots go over the line. He thanked Mr. Milton for having mentioned another advantage due to the new arrangement. He agreed that the proper combustion of gases was more important than extra heating surface. In regard to the two curves on his diagram showing too great an advantage for the economizer, he would point out that he only attempted in his paper to describe experiments, and the results given were those obtained, although, perhaps, the records might be a little too favorable if ordinary working conditions were taken. In the first set of experiments they had made, the feed had been put into the top vessel in the old way. Certain things had occurred, however, which made the change to the arrangement shown desirable. As to circulation being uncertain in the middle tubes, that was not a fact. It might be thought

that the water would be uncertain whether it should go up or down, and, however this might be at first, when the water once started going a certain direction it was very difficult to stop it. It was an example of the old adage, "Train up a child in the way it should go." Mr. Macfarlane Gray's remarks were very instructive. It would seem at first that no advantage could be gained by heating feed water with live steam; the fact was, however, that if the water were heated to the point of ebullition it would fly into steam directly it touched the heating surface. In this way motion would be created, and there would not be still water, which it was well known did not absorb heat so fast as water in motion. It is easy enough to try this experiment: let anyone put the hand into a basin of water and gradually add hot water. This could be done for a long time, so long as the hand were kept still, but if it were moved about the heat would be felt.

U. S. STEAMER *FULTON*—HER DESIGN, CONSTRUCTION AND CAPACITY.

By Charles H. Haswell, Civil and Marine Engineer.

As this was the first sea steamer constructed by the United States Navy, a record of her design, construction and capacity may be held to be of interest.

Upon her construction being ordered by Congress, the Secretary of the Navy, Mahlon Dickerson, directed the Commissioners of the Navy (a board of three officers discharging the duties now confided to the various bureaus) to proceed with the work; whereupon they detailed Chief Naval Constructor Samuel Humphreys and Constructors John Lenthall and Samuel Hartt to design the vessel. They, in order to assure themselves of the additional required capacity of hull for the engines and boilers, assembled at New York and, in default of the assistance of an engineer, consulted with James P. Allaire, the principal manufacturer of steam engines, who recommended two vertical overhead-beam engines. Upon the exposure of such vital parts of the engines as the beams and connections being objected to, he replied that the chances of such exposed parts being injured by a shot were inconsiderable compared with the advantage of that type of engine for such a design and construction of hull as that proposed. They then advised with William Kemble, of the West Point Foundry Association, who gave them more of a dissertation on steam and engines than the recommendation of any one.

They then consulted with a manufacturer of steam engines whose plant was restricted to the construction of shop engines and light machines. He, in compliance with a very general and recognized law of individuals—that of holding his interest superior to that of others—recommended four non-condensing engines, set under the deck, and plain cylindrical boilers, which design being

approved by the constructors, the additional capacity of the hull required was determined by the requirements of such a plant, and the following dimensions were decided upon, viz: Length, 150 feet; beam, 34 feet 5 inches; hold, 12 feet 2 inches; and load line, 5 feet 3 inches.

When the hull was in frame, beamed, decked and planked, an engineer was appointed temporarily to submit a design of engines and boilers, whereupon he designed two condensing engines, but from the insufficient depth of the hold for such an immersed midship section, the cylinders were necessarily set on the spar deck beams at a slight inclination thereto. Upon his design being approved he was, on the 12th July, 1836, appointed Engineer in the Service, and the superintendence of the construction of the engines and boilers of the vessel was confided to him.*

Upon consideration of the insufficiency of the capacity of the hull for engines and boilers of suitable capacity, and of the very insufficient capacity of coal hold, he addressed the Commissioners of the Navy, recommending that the hull be lengthened 20 feet, (he preferred 30 feet, but was afraid to go to such an extent). Unfortunately and regretfully, his recommendation was not approved by the Chief Naval Constructor, to whom it was referred, added to which the engineer nearly lost his further employment for his temerity and such an alleged evidence of his incapacity.

Soon after, a contract was made with the West Point Foundry Association for two inclined condensing engines and the construction of four boilers, formed of the copper plates which were in a store house in the Navy Yard, and which had been procured in 1816 for the construction of a second *Flogobombus.*

To accommodate the engines, two deck beams were cut out between the engine frame and one other scored. The water wheel shafts were about 3 feet above deck; the boilers, condensers, air pumps, etc., below. The volume of all of these reduced the capacity of the hold to such an extent that the fuel capacity was restricted to one day's steaming, added to which the weight of the engines and boilers was so much over that for which the

* This engineer was Mr. Haswell himself, who was thus the first engineer of the United States Navy.—ED.

hull was designed, that the load draught was increased from 5.25 to 10.25 feet.

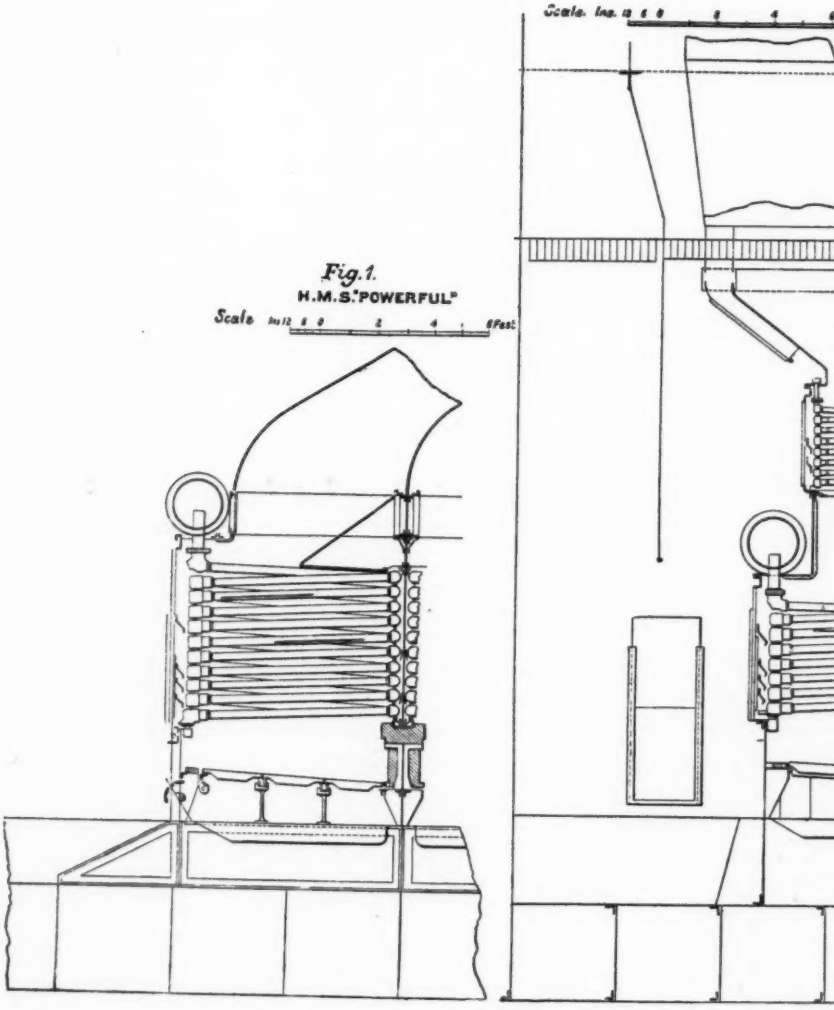
In April, 1838, the vessel, under the command of Capt. M. C. Perry, left New York for Washington. At Cape May her coal hold was filled with pine wood, at Norfolk a second supply of wood was obtained, and a third on the Potomac river.

Upon her arrival at Washington it was decided, in order to increase the quarters of her officers, to remove the cabin to the upper deck, and also that a hurricane deck should be added amidships, the weight of both of which additions increased her draught to 10.5 feet.

In September, under the command of Capt. Charles W. Skinner, she left Washington and reached Norfolk. While there the Department learned of its having been stated at a dinner table in New York that the British steamer *Great Western*, then plying between that city and Liverpool, could beat her in speed. My deliberate opinion was called for, and, upon my comparison of the relative powers and immersed sections and lines of the two vessels, the result of my reply was such that the vessel immediately left for New York. A few days after her arrival, due notice of the intention to test the speed of the two vessels having been given, the *Fulton*, with several prominent merchants of the city on board, proceeded to the upper bay and awaited the *Great Western* as she left the city on her outward voyage. After allowing her to pass and have a full lead (professionally to write), the *Fulton* "opened" and passed her competitor so fast that to the observers on the *Fulton* she never closed the land abeam and ahead of her.

Soon after the engineer was detached from her for other service, and two years after, in order to reduce her draught of water, two of her boilers were removed and the remaining ones lengthened.

BOILERS OF H.M.SS. "PO



OWERFUL" AND "DIADEM."

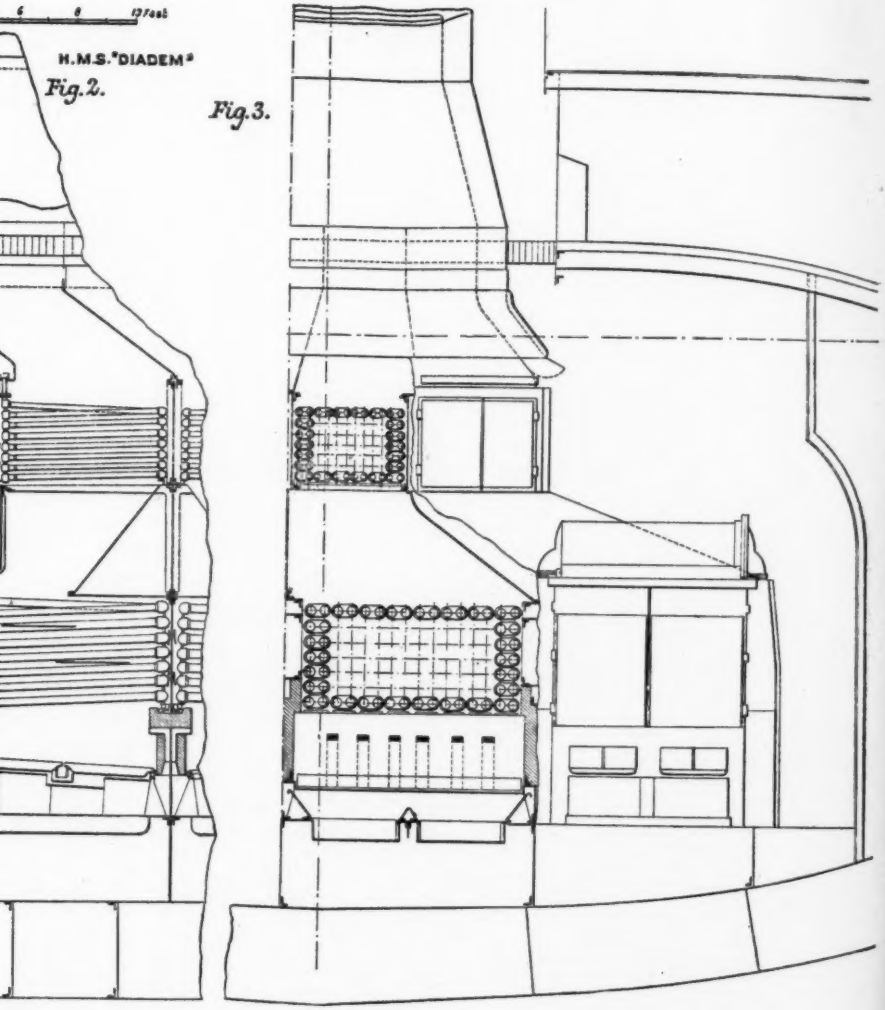


Fig.2.

Fig.3.

RECENT TRIALS OF THE CRUISER *DIADEM.**

By Sir John Durston, K. C. B., R. N., Engineer-in-Chief of H. M. Navy, Vice-President I. N. A.

The author had the honor in April, 1897, to submit to the Institution some notes on the trials of the cruisers *Powerful* and *Terrible*, the first ships in our navy of large power fitted with water-tube boilers of the Belleville or large tube type, and the present paper, respecting the trials of the cruiser *Diadem*, is submitted as a supplement or a continuation of those notes.

While the boilers of the first four vessels of the *Diadem* class were under construction, trials at Paris of Belleville boilers fitted with economizers showed considerable advantages over the *Powerful* type of boiler, in economy of fuel, less tendency to production of smoke, and lower funnel temperatures. Consequently, it was decided to alter the boilers of the vessels of this class by reducing the number of generator tubes, and fitting economizers, as shown in Figs. 1, 2 and 3, which give longitudinal sections of the boilers of *Powerful* and *Diadem*, and also a transverse view showing two boilers of the last named ship, one being shown in section and the other in elevation.

Comparing the section of the boilers of *Diadem* with that of the *Powerful* type of boiler, it will be seen that the number of rows of $4\frac{1}{2}$-inch generating tubes in each element has been reduced from ten to seven, while over the generating tubes there is a space provided corresponding to that of the combustion chamber in an ordinary return-tube cylindrical boiler, and above this space is situated another nest of tubes of smaller ($2\frac{3}{4}$-inch) diameter, and seven rows in height, forming the economizer. The furnace air-blowing engines supply jets of air to this space as well as into the furnaces below. The feed water is pumped

* Paper read before the Institution of Naval Architects.

into the lower part of the economizer, traverses to the top of its elements, and from thence it is led to the steam collector for feeding the generating tubes.

The advantages of this arrangement are that the combustion is more effectually completed, the escaping funnel gases are of a much lower temperature, firing does not require so much attention, and a considerable economy in fuel is obtained.

Table D shows the disposition of heating surfaces and the weights in representative eight-element boilers in *Powerful* and *Diadem* respectively.

TABLE D.—COMPARISON OF BOILERS OF H.M.S. *POWERFUL* AND *DIADEM*.

(The data are for one boiler only in each case.)

Ship.	Number of elements.		Heating surface.			Fire grate.	Weight of boiler with furnace fittings, casings, lagging, and mountings, complete.	Weight of water.	Total weight.
	Generator.	Economizer.	Generator.	Economizer.	Total.				
			sq. ft.		*sq. ft.*	*sq. ft.*	*tons.*	*tons.*	*tons.*
Powerful...	8	nil.	1,420	...	1,420	49	17.4	1.1	18.5
Diadem.....	8	6	995	335	1,350	49	16.7	1.3	18.0

It will be observed that there is a slight increase in weight of water due to the economizer, but this does not interfere with the tactical advantage possessed by the boiler in raising steam quickly, for the amount of water in the generator portion is reduced. The machinery of the *Diadem* class is designed to attain a maximum power of 16,500 indicated horse power, and a continuous sea-going power of 12,500 indicated horse power for as long as the coal lasts.

The specified trials were:

1. An eight-hours' trial at 16,500 indicated horse power with all boilers in use.

2. A thirty-hours' trial at 12,500 indicated horse power with all boilers in use.

3. A thirty-hours' trial at 3,300 indicated horse power with

the number of boilers at discretion of contractor. (Only the after set of eight boilers, or 27 per cent. of the total boiler capacity, was actually used.)

The maximum pressure at which the engines were specified to work was 250 pounds per square inch, with a boiler pressure of 300 pounds, an increase of 40 pounds beyond that specified for the *Powerful* and *Terrible*. The engines are of a similar type to those of the *Powerful* and *Terrible*, two low-pressure cylinders being fitted, *i. e.*, the engines are of the four-cylinder, triple-expansion type. The diameters of the cylinders are as follow:

High-pressure, inches,	34
Intermediate-pressure, inches,	55½
Two low-pressure, each, inches,	64

The stroke is 4 feet, with a designed cut-off in the high-pressure cylinder of 73 per cent. The ratio of low-pressure to high-pressure cylinder volume is 7.08. Allowing for a clearance in the high-pressure cylinder of 25 per cent., and in the low-pressure cylinder of 15 per cent., the designed real ratio of expansion at full power was about 8.3.

The cylinders are arranged as in the *Powerful*, with the high-pressure cylinder forward and the two low-pressure cylinders aft. The two low-pressure cranks are opposite each other, and the two high-pressure and intermediate-pressure cranks also opposite each other, but at right angles to the low-pressure cranks. The high-pressure and intermediate-pressure cylinders are arranged with centers as close together as possible, the valve casings of each of these two cylinders being for this purpose placed away from the other cylinder. The two low-pressure cylinders are similarly arranged; the moments of the forces therefore causing vibration are relatively small. It may be stated that throughout the whole range of power and revolutions developed in these trials the vibration was inappreciable. There are no balance weights nor any special means of reducing vibration beyond the arrangement of cranks and disposition of cylinders. All the cylinders are steam-jacketed, those of the intermediate-pressure and low-pressure cylinders only were used on the trials, the pressure

maintained in these jackets being regulated to approximately equal their respective receiver pressures.

The boilers are thirty in number, twenty of them containing eight generator elements and six economizer elements, six having seven generator elements and six economizer elements, and the remaining four containing nine generator elements and seven economizer elements, this distribution being dependent upon the width of stokeholds available in the various sections of the ship. The boilers are arranged in four compartments, with tubes fore and aft, eight in each of the three after and six in the forward one, placed back to back, in each compartment. The gases are led into four funnels, and the uptake leads from the boilers are practically vertical. Each boiler compartment has a separate main steam pipe and feed system, the four main steam pipes being carried to the forward bulkhead of engine room, with the usual stop valve to each pipe at the bulkhead.

The total heating surface of the boilers, as originally designed, was 42,270 square feet, or 2.56 square feet per indicated horse power. After the boilers were modified the heating surface in the generator portion was reduced to 29,600 square feet, or 1.8 square feet per indicated horse power; while in the economizers an addition was made of 10,950 square feet, or .66 square feet per indicated horse power, making a total surface of 40,550 square feet, or 2.46 square feet per maximum specified indicated horse power.

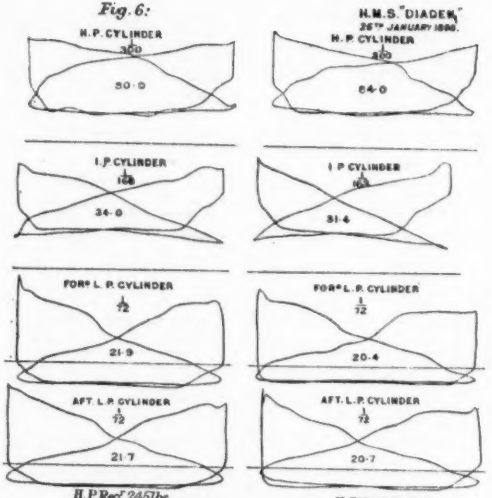
There are four main feed pumps and four auxiliary feed pumps, but, unlike the *Powerful* and *Terrible*, the main feed pumps and separators are placed in the boiler compartments instead of in the engine room. The usual stokehold fans necessary to insure a constant supply of air from the upper deck in all circumstances and air-blowing engines for the purpose of supplying air in jets to mix the furnace and combustion-chamber gases and assist the combustion, are fitted.

Table A gives the detailed results of all the trials carried out, and average sets of indicator diagrams are shown in Figs. 4 to 7.

The first trial was the contract 30-hours' trial at 3,300 indicated horse power—*i. e.*, one-fifth the designed maximum

Fig. 4.
H.M.S. "DIADEM"
H.P. CYLINDER
I.P. CYLINDER
FORE L.P. CYLINDER
AFT. L.P. CYLINDER
STARBOARD ENGINE
PORT ENGINE
Fig. 5.
H.M.S. "DIADEM"
H.P. CYLINDER
I.P. CYLINDER
FORE L.P. CYLINDER
AFT. L.P. CYLINDER
STARBOARD ENGINE
PORT ENGINE
COLLECTIVE I.H.P. 13200.

Fig. 6:

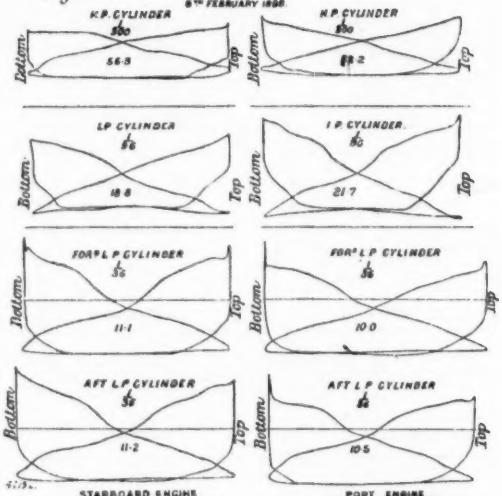


STARBOARD ENGINE.		PORT ENGINE
H.P. Recr. 245 lbs.		H.P. Recr. 243 lbs.
Vac. 27 ins.		Vac. 26½ ins.
Revs. 119·68		Revs. 119·73
I.H.P. H. 2369·6		H. 2212·6
I. 2386·1		I. 2204·5
F.L. 2044·8		F.L. 1805·1
A.L. 2016·6		A.L. 1933·1
Total I.H.P. 8816·6		Total I.H.P. 8155·3

COLLECTIVE I. H. P. 17080

Fig. 7.

H.M.S. DIADEM
8TH FEBRUARY 1899.



STARBOARD ENGINE		PORT ENGINE
H.P. Recr. 156 lbs.		H.P. Recr. 160 lbs.
Vac. 26 ins.		Vac. 25½ ins.
Revs. 88·40		Revs. 85·43
I.H.P. H. 1109·6		H. 1027·0
I. 872·5		I. 738·0
F.L. 765·3		F.L. 697·5
A.L. 772·2		A.L. 732·3
Total I.H.P. 3616·6		Total I.H.P. 3594·8

COLLECTIVE I. H. P. 7211

power—and the results are given. Eight boilers, with eight elements each, out of the thirty boilers were used, the mean power being 3,318, the coal consumption per indicated horse power per hour being 2.18 pounds, or 18.4 pounds per square foot of grate per hour.

It should be observed that during this and all subsequent trials the necessary auxiliary machinery was at work, and the coal consumption includes the expenditure for this purpose, no deduction having been made on this account and no additions having been made to the indicated horse power shown by the main engines. The coal used, therefore, includes that for the auxiliary engines connected with the main engines—the evaporating apparatus, steering engine, and a 600-ampere dynamo supplying electric light to the whole ship.

The second trial was the contract 30-hours' at 12,500 indicated horse power—*i. e.*, about 75 per cent. of the maximum specified power—with all boilers in use. The trial was carried out in a very satisfactory manner, the power realized being 12,813, while the coal consumption, taken as defined in the contract, for 24 consecutive hours, was 1.59 pounds per indicated horse power, or 13.9 pounds per square foot of grate per hour. During this trial three runs were made over the measured long-distance course (23 nautical miles) between Rame Head and Dodman Point, when, with no wind and a calm sea, a mean speed of 19.79 knots was realized. The boilers generated steam freely, the stokeholds being open and the fans not in use.

The third contract trial—*i. e.*, at 16,500 indicated horse power for eight hours, with all boilers in use—was carried out on January 26, when a mean collective indicated horse power of 17,262 was obtained with open stokeholds and the ventilating fans running slowly.

The coal consumption was 1.76 pounds per indicated horse power, or 20.8 pounds per square foot of grate per hour. The speed of the vessel was again tested by three runs over the long-distance course between Rame Head and the Dodman; 20.6 knots was the mean of the three runs, but, as the first two runs were made on slack water and the third against a tide, there is

no doubt that the true speed is higher than this figure. The mean of the first two runs was 20.72 knots.

In addition to the preceding contract trials the following experimental trials were carried out:

In the first place, it was desired to test the capability of these modified boilers when being pressed beyond the amount necessary to obtain the specified maximum power. For this purpose a trial of four hours was made on January 29 with the three after stokeholds only, the boilers in which amounted to 78 per cent. of the total boiler power of the ship, developing about the specified maximum power. On this trial the horse power realized was 15,861, the coal consumed per indicated horse power per hour being 1.95 pounds, and the coal burnt per square foot of grate, 27.1 pounds per hour. The boilers generated steam for this power satisfactorily, but accelerated draft was necessary to the extent of $\frac{3}{10}$ inch of air pressure in the stokeholds. With a higher air pressure, no doubt the proportion of boilers used would have generated a still higher power, but it was considered undesirable to press them further than beyond the contract amount. It will be observed that on this trial the combined heating surface in the generators and economizers was at the rate of about 2 square feet per indicated horse power.

On February 10 and 11 similar trials were made with the same boilers, *i. e.*, 78 per cent. of the total boiler surface, to test their capacity for maintaining for long periods a higher power than contracted for, and it was endeavored to obtain with this proportion of boiler power the full continuous steaming power, *i. e.*, 75 per cent. of maximum power specified to be obtained with the whole of the boilers at work. This was successfully realized, and, with open stokeholds, 12,852 indicated horse power was maintained for thirty hours, the coal consumption per indicated horse power being 1.88 pounds per hour, or 21.2 pounds per square foot of grate. On this trial the coal, although hand-picked, was of an inferior quality as regards quantity of clinker, which necessitated the fires being cleaned much oftener than usual. They were completely cleaned each eight hours, and this largely accounts for the difference in coal consumption between this trial

TABLE A.—MEAN RESULTS OF

Name of ship.	Description of trial.	Proportion of full designed power developed.	Number of boilers in use on the trial.	Grate area in use.	Heating surface in use.	Steam pressure (by gauge).		Fall of pressure from H.P. receiver to steam line of H.P. diagrams.		Jacket pressures (by gauge).		
						Boilers.	Engines.	At commencement of stroke.	At middle of steam admission line.	H.P.	I.P.	L.P.
				sq. ft.	*sq. ft.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
Diadem	Contractors'. 30 hours' coal consumption.	.201	8	392	10,820	265	202	5	21	123	57	11.7
Do.	Contractors'. 30 hours' coal consumption.	.776	30	1,462	40,550	280	245	2	22	0	96	25
Do.	Contractors'. 8 hours' full power.	1.046	30	1,462	40,550	291	249	1	26	0	117	35
Do.	4 hours' trial	.961	24	1,140	31,720	291	239	1	26	0	115	30
Do.	15 hours' trial	.198	8	392	10,820	275	244	2	27	0	71	15
Do.	15 hours' trial	.431	16	784	21,640	257	156	4	23	0	96	13.5
Do.	30 hours' trial	.78	24	1,140	31,720	265	240	5	21	0	107	30
Recent representative battleship.	30 hours' coal consumption.	.518	8	820	25,045	139	136	18	40	133	40	10.1
Do.	8 hours' natural draft.	.872	8	820	25,045	150	148	5	20	133	17	7.7
Do.	4 hours' full power.	1.023	8	820	25,045	152	147	6	23	146	49	13.1
Recent representative second-class cruiser.	30 hours' coal consumption.	.513	8	626	18,700	145	142	3	21	Not used	38	8.5
Do.	8 hours' natural draft.	.855	8	626	18,700	149	149	4	18	Not used	56	13.5
Do.	4 hours' full power.	1.025	8	626	18,700	151	149	7	14	Not used	65	16.5

(*a*) At 67.35 revolutions. (*b*) At 109.86 revolutions. (*c*) At 118.78 r
(*e*) Mean of first two runs, 118.59 revolutions.

OF THE TRIALS OF H.M.S. *DIADEM*, AND TWO VESSELS WITH CYLINDRICAL BOILERS.

	Receiver pressures (by gauge).			Mean effective pressures in the cylinders.				Mean cut-off in H.P. cylinder.	Vacuum in condensers.	Revolutions of main engines per minute.	Indicated horse power (total).	Mean effective pressure referred to the L.P. cylinder.	Absolute pressure at release in the L.P. cylinder.	Total ratio of expansion on trial.	Coal used per hour.		
	H.P.	I.P.	L.P.	H.P.	I.P.	L.P.									Per square foot of grate.	Per I.H.P.	
						Forward.	Aft.										
	lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*		*ins. of mercury.*								*ft.*
	170	54	9.2	31.02	10.44	7.15	7.87	.27	27.1	67.24	3,318	15.8	6.4	15.7	18.4	2.18	1
	241	97	26	79.0	28.07	16.4	16.46	.54	26.7	107.67	12,813	38	12	10.3	13.9	1.59	1
	245	117	36	88.87	33.56	21.09	21.44	.68	26.7	119.1	17,262	46.5	16	8.7	20.8	1.76	1
	235	113	32	84.18	33.76	19.0	19.31	.68	26.7	116.3	15,861	43.7	15.8	8.7	27.1	1.95	1
	176	61	11.2	30.81	10.71	7.57	8.02	.27	26.5	64.7	3,266	16.2	6.9	15.7	19.6	2.35 (*d*)	1
	151	58	12	53.84	20.0	10.22	10.56	.54	26.1	89.5	7,119	25.5	8.5	10.3	17.6	1.94 (*d*)	1
	237	102	24	79.15	30.56	15.42	16.06	.54	26	107.2	12,852	38.4	12	10.3	21.2	1.88 (*d*)	1
	136	37	3.6	32.43	19.00	8.68		.555	27.7	82.91	6,216	23.8	8	...	13.8	1.82	
	148	56	11.1	48.24	25.07	13.13		.638	25.6	97.16	10,465	34.3	11.7	...	29.5	2.3	
	147	59	13.6	54.14	28.04	14.69		.707	26.4	101.8	12,280	38.4	14.0	...	Not taken	...	
	141	46	6.5	38.35	18.55	8.9		.39	26.6	117.85	4,925	24.7	7.9	...	12.6	1.6	
	146	55	10	54.0	28.55	12.3		.63	28.1	136.15	8,208	35.6	11.2	...	28.8	2.2	
	146	53	12	66.65	30.45	13.5		.75 to .69	27.9	144.95	9,840	40.1	14.0	...	Not taken	...	

78 revolutions (mean of three runs over deep sea course). (*d*) Coal hand-picked, but very productive of clinker. Fires cleaned practically ever
s. The first two runs were made in slack water, and the third against the tide, so that this is probably the more correct figure.

TABLE A.—MEAN RESULTS OF THE TRIALS OF H.M.S. *DIADEM*, AND TWO VESSELS WITH CYLIN

Steam pressure (by gauge).		Fall of pressure from H.P. receiver to steam line of H.P. diagrams.		Jacket pressures (by gauge).			Receiver pressures (by gauge).			Mean effective pressures in the cylinders.				Mean cut-off in H.P. cylinder.	Vacuum in condensers.
Boilers.	Engines.	At commencement of stroke.	At middle of steam admission line.	H.P.	I.P.	L.P.	H.P.	I.P.	L.P.	H.P.	I.P.	L.P.			
												Forward.	Aft.		
lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*		*ins. of mercury.*
265	202	5	21	123	57	11.7	170	54	9.2	31.02	10.44	7.15	7.87	.27	27.1
280	245	2	22	0	96	25	241	97	26	79.0	28.07	16.4	16.46	.54	26.7
291	249	1	26	0	117	35	245	117	36	88.87	33.56	21.09	21.44	.68	26.7
291	239	1	26	0	115	30	235	113	32	84.18	33.76	19.0	19.31	.68	26.7
275	244	2	27	0	71	15	176	61	11.2	30.81	10.71	7.57	8.02	.27	26.5
257	156	4	23	0	96	13.5	151	58	12	53.84	20.0	10.22	10.56	.54	26.1
265	240	5	21	0	107	30	237	102	24	79.15	30.56	15.42	16.06	.54	26
139	136	18	40	133	40	10.1	136	37	3.6	32.43	19.00	8.68		.555	27.7
150	148	5	20	133	17	7.7	148	56	11.1	48.24	25.07	13.13		.638	25.6
152	147	6	23	146	49	13.1	147	59	13.6	54.14	28.04	14.69		.707	26.4
145	142	3	21	Not used	38	8.5	141	46	6.5	38.35	18.55	8.9		.39	26.6
149	149	4	18	Not used	56	13.5	146	55	10	54.0	28.55	12.3		.63	28.1
151	149	7	14	Not used	65	16.5	146	53	12	66.65	30.45	13.5		.75 to .69	27.9

(*b*) At 109.86 revolutions. (*c*) At 118.78 revolutions (mean of three runs over deep sea course). (*d*) Coal hand-p
(*e*) Mean of first two runs, 118.59 revolutions. The first two runs were made in slack water, and the third against the tide, so that thi

Revolutions of main engines per minute.	Indicated horse power (total).	Mean effective pressure referred to the L.P. cylinder.	Absolute pressure at release in the L.P. cylinder.	Total ratio of expansion on trial.	Coal used per hour.		Propellers.				Speed on measured mile or deep sea course.	Date of trial.
					Per square foot of grate.	Per I.H.P.	Diameter.	Pitch.	Slip per cent.	Expanded blade area of each.		
							ft. ins.	*ft. ins.*		*sq. ft.*	*knots.*	
67.24	3,318	15.8	6.4	15.7	18.4	2.18	16–9	22–11$\frac{1}{8}$	16.4	58	12.74 (*a*)	January 18 and 19
107.67	12,813	38	12	10.3	13.9	1.59	16–9	22–11$\frac{1}{8}$	20.3	58	19.79 (*b*)	January 21 and 22
119.1	17,262	46.5	16	8.7	20.8	1.76	16–9	22–11$\frac{1}{8}$	23.3 22.8	58	20.6 (*c*) 20.72 (*e*)	Jan. 26
116.3	15,861	43.7	15.8	8.7	27.1	1.95	16–9	22–11$\frac{1}{8}$	...	58	Not taken	Jan. 29
64.7	3,266	16.2	6.9	15.7	19.6	2.35 (*d*)	16–9	22–11$\frac{1}{8}$	...	58	"	Feb. 7
89.5	7,119	25.5	8.5	10.3	17.6	1.94 (*d*)	16–9	22–11$\frac{1}{8}$	...	58	"	Feb. 8
107.2	12,852	38.4	12	10.3	21.2	1.88 (*d*)	16–9	22–11$\frac{1}{8}$	...	58	"	Feb. 10–11
82.91	6,216	23.8	8	...	13.8	1.82	...	...	...	...	...	...
97.16	10,465	34.3	11.7	...	29.5	2.3	...	...	...	...	...	...
101.8	12,280	38.4	14.0	...	Not taken	...	...	...	...	...	...	...
117.85	4,925	24.7	7.9	...	12.6	1.6	...	...	...	...	...	...
136.15	8,208	35.6	11.2	...	28.8	2.2	...	...	...	...	...	...
144.95	9,840	40.1	14.0	...	Not taken	...	...	...	...	...	...	...

nd-picked, but very productive of clinker. Fires cleaned practically every eight hours.
this is probably the more correct figure.

and the corresponding one with the whole of the boilers at work. A certain increase would, however, be expected, due to the higher rate of combustion at which the boilers were being worked.

Another trial was made on February 7 of fifteen hours' duration under exactly the same circumstances as the first contract trial, with a view of confirming or otherwise the coal consumption then shown; but, unfortunately, the coal in the bunkers on this trial was much inferior, and produced a much larger amount of clinker; 3,266 indicated horse power was obtained, and the coal consumption was 2.35 pounds per indicated horse power, as against the 2.18 obtained on the original trial, and the difference between these two figures may be regarded as entirely due to the quality of the coal, and to the constant cleaning and clinkering necessary. On the succeeding ships of the class, two of which will probably be tried within the next three months, this question of consumption at one-fifth power will be further tested. With a larger proportion of boilers in use for this low power, say, twelve instead of eight, better results may be obtained.

A further trial was made of fifteen hours duration on February 8, to compare the powers developed in the engines, using 150 pounds steam pressure, with that obtainable at 250 pounds pressure, the cut-off in the cylinders being the same. The trial selected for comparison was the second contract trial, and the links were therefore set at the same position as they were on the trial of January 21, when an indicated horse power of 12,813 was obtained. The mean power at this reduced pressure was 7,119, the revolutions being 89.5, as against the 107.6 on the original trial. The power was, therefore, about 60 per cent. of that obtained with 250 pounds pressure. The coal consumption was 1.94 pounds per indicated horse power per hour. As the same inferior quality of coal as regards clinker was used, this consumption is, no doubt, higher than would otherwise have been the case. On all the contract and experimental trials the pressure of steam in the supply pipes to the auxiliary machinery was restricted by reducing valves to about 150 pounds per square inch.

On the trials of the *Powerful* and *Terrible* it was found particularly necessary to regulate the firing, while on the trials of the

Diadem, with the modified type of boiler, such close attention, although beneficial, was found to be not so necessary, and more latitude in thickness and level of fire is permissible.

A comparison of weights per indicated horse power in recent designs similar to that given last year for the *Powerful* is given in Table B.

The *Diadem* and *Powerful* are compared in Table B with nine recent battleships with cylindrical boilers and 155 pounds steam pressure. It will be seen that the percentage of increase of power per ton weight of boilers and fittings, comparing the full power of the *Diadem* with the natural-draft power of the nine battleships, is 58.4 per cent., while in the *Powerful* the corresponding figure is 54.5 per cent. Comparing the *Diadem* and the *Powerful*, the specified power in the latter was 31.66 indicated horse power per ton of machinery weights in engine room; while in the former it was 28.62, the heavier weight of the *Diadem* engines being largely accounted for by the larger ratio of cylinders fitted; *i e.*, a ratio of 7 to 1 against 5.7 to 1.

A series of trials in connection with the auxiliary machinery, which were carried out in the vessel while in basin, preliminary to these speed and power trials taking place, will now be referred to. The coal consumption for auxiliary purposes—*i. e.*, for purposes not required simply for propelling the vessel—as reported in some recent ships, was considered abnormally high, and the opportunity was taken to test the quantities of steam or coal required for such purposes only, by a series of trials with the engines at rest and the ship in the basin. These trials were made with two boilers in use, each trial being of eight hours duration, and the amount of coal burnt was measured when various combinations of auxiliary engines were at work. For example, trials were made with certain auxiliary engines in use, and also the electric-light installation and distilling plant, and the trials were repeated with these latter engines stopped, so that, by a process of subtraction, the amount of coal used by the electric-light installation was ascertained.

The figures in Table C give a summary of the results obtained. They are not uniformly consistent, and, in considering some of

TABLE B.—WEIGHTS OF MACHINERY OF RECENT BRITISH SHIPS WITH BELLEVILLE AND WITH CYLINDRICAL BOILERS.

Ship.	Indicated Horse power.	A. Weight of machinery in engine rooms.	Indicated horse power per ton of *A*.	B. Weight of propellers, etc.	Indicated horse power per ton of *B*.	C. Total weight of main engines, propellers, etc., $= A + B$.	Indicated horse power per ton of *C*.	D. Weight of boilers and fittings.	Indicated horse power per ton of *D*.	E. Total weight of main machinery and boilers $= A + B + D$.	Indicated horse power per ton of *E*.
		tons.		*tons.*		*tons.*		*tons.*		*tons.*	
Average of nine recent battleships.	10,000 (N.D.)	445.01	22.47	98.17	101.86	543.18	18.41	719.31	13.92	1262.49	7.92
	12,000 (F.D.)	...	26.96	...	122.23	...	22.092	...	16.706	...	9.505
Powerful	25,000	789.5	31.66	192.72	129.7	982.2	25.45	1162.05	21.51	2144.27	11.7
Percentage of increase over battleships.	Compared with N.D.	...	...	...	...	...	...	...	54.52	...	...
	Compared with F.D.	...	17.433	...	6.126	...	15.20	...	28.75	...	...
Diadem	16,500	576.45	28.62	111.9	147.45	688.35	23.97	748.4	22.05	1436.75	11.48
Percentage of increase over battleships.	Compared with N.D.	...	...	...	...	...	...	...	58.405	...	...
	Compared with F.D.	...	6.16	...	20.63	...	8.501	...	31.988	...	20.778

the figures, allowance must be made for the inevitable variation in stoking and possible differences due to variations in the conditions of the fires at the beginning and end of each trial and to the small quantities of coal burnt per square foot of grate. The figure 3.75 tons in trial M, even assuming it may be slightly underestimated, owing to varying conditions above mentioned, indicates a high economical performance in both the engines and boilers in use, particularly as deductions must be made for coal expended in simply maintaining pressure in the large system of pipes in use (suggested by trials C and D).

It will be seen, by comparing trials G with I and H with J, that the length of steam pipe in use has an important bearing on the coal consumption. The conditions in G and H were the same as in I and J, respectively, except that two of the extreme after boilers were in use in the latter trials, and two of the extreme forward boilers in trials G and H. A saving of 20 per cent. to 30 per cent. of the total coal used was effected by the use of the after boilers—*i. e.*, those with the shortest steam pipes.

A comparison of trials A and G, in which latter a saving of 15 per cent. of coal is effected, over trial A, by using a lower pressure of steam, indicates that it is not desirable to use the higher pressures of steam which can be carried in the boilers when working the auxiliary engines, and this lower pressure of steam was used on the subsequent trials under way. The main engines are designed to work at the high grades of expansion necessary for obtaining the increased economy to which the high-pressure steam lends itself; but, as the degree of expansion in many of the auxiliary engines is either non-existent or very limited, particularly in such engines as feed engines, blowing engines, and auxiliary circulating engines, which are simple engines with very late cut-off, no advantage is obtained by increasing the pressure beyond that which is absolutely necessary to obtain the full work out of the engines in use. In the present case that pressure is about 155 pounds in the electric-light engines, and 179 pounds in the refrigerator engines, both these engines having compound cylinders.

Assuming a water consumption for the electric-light engine

Duration of trials. Hours.	Boilers in use. Numbers.	Distinguishing letter of trials.	Steam pressure, pounds per sq. in.		Blowing engine. One steam cylinder, 9¼ inches diameter, 9 inches stroke.		Electric light engine. Steam cylinders, high pressure, 7½ inches diameter, 9 inches stroke, and low pressure, 15 inches diameter, 9 inches stroke.			Auxiliary circulating pump. One steam cylinder, 7 inches diameter, 7 inches stroke.	S
			Boiler room.	Engine room.	Revolutions per minute.	Pressure of air, pounds per sq. in.	Revolutions.	Volts.	Ampères.	Revolutions per minute.	
8	1 and 2	A	280	272	96.1	6.6	309	79.9	599.3	85.2	
8	1 and 2	B	280	274.8	80.4	6	...	...	...	94.6	
8	1 and 2	C	280.6	274.9	71.8	5	...	...	...	82.9	
8	1 and 2	D	150.6	150.1	72.3	5	...	...	...	81.3	
8	1 and 2	E	280	275.3	73.0	5	...	...	...	82.25	
8	1 and 2	F	150	150	73.2	5	...	...	...	70.6	
8	1 and 2	G	160	156.3	73.6	5	300.7	80	600	92.8	
8	1 and 2	H	160	155	73.8	5	304	80	600	85.7	
8	29 and 30	I	160	155	73.6	5	309.6	80	600	81.2	
8	29 and 30	J	160	155	73.0	5	315	80	600	83.5	
8	1 and 2	K	160	155	73.8	5	320	80	600	82.3	
8	1 and 2	L	160	155	73.87	5	320	80	600	81.8	
8	1 and 3	M	183.4	178.4	100	8	315	80	600	119.2	

AUXILIARY MAC

On trials A, G, I, K and L.—One main feed pump, one blowing engine, one auxiliary circ
On trial B.—Same as A, G, I, K, L, with the exception of electric-light engine being stop
On trials C, D, E and F.—One main feed pump, one blowing engine and one auxiliary ci
On trials H and J.—Same as G, except that the evaporators were not in use.
On trial M.—One main feed pump, one blowing engine, one auxiliary circulator, one elect

* Measured water made per hour.

TABLE C.

Refrigerating engine. Steam cylinders, high pressure, 5¼ inches diameter, low pressure, 10⅜ inches, stroke 12 inches. Revolutions.	Feed engine. One steam cylinder, 16¼ inches diameter, 18 inches stroke.	Evaporator primary steam. Pressure per sq. in.	Distiller pumps. One steam cylinder, 6 inches diameter, 7 inches stroke. Revolutions. Starboard.	Distiller pumps. One steam cylinder, 6 inches diameter, 7 inches stroke. Revolutions. Port.	Water made, gallons per hour.*	Total water made, including coil drain, tons per day.†	Pounds of water evaporated per pound of coal.	Water pumped from feed tank, pounds per hour.	Coal Consumption. Pounds per hour.	Coal Consumption. Tons per day.	Distinguishing letter of trial.	
...	From 1 to 3 double strokes per minute.	147.5	78.1	83.8	247.6	59.6	Not taken	Not taken	975	10.4	A	T
...		102.0	83.1	95.6	170.4	41.8	Do.	Do.	625	6.6	B	N
...		...	...	...	...	...	Do.	Do.	250	2.6	C	A
...		...	...	...	...	...	Do.	Do.	237.5	2.5	D	
...		...	...	...	...	...	Do.	Do.	525	5.6	E	
...		...	...	...	...	...	Do.	Do.	312.5	3.3	F	
...		112.7	79.7	78.4	236.1	56.9	8.79	7,255.0	825	8.8	G	
...		...	...	...	...	...	7.23	4,160.0	575	6.1	H	
...		112	78.7	79.1	198.6	47.8	10.56	7,001.0	662.5	7.09	I	
...		...	...	...	...	...	10.21	3,710.0	362.5	3.88	J	
...		113.1	79.0	79.0	203.8	49.05	8.96	6,947.5	775	8.3	K	
...		112.1	78.0	79.0	215.8	52.02	9.10	7,435.0	812.5	8.7	L	
118.2		...	...	...	...	...	...	...	350	3.75	M	

ACHINERY IN USE ON THE SEVERAL TRIALS.

circulator, one electric-light engine, two distiller pumps and two evaporators working compound.

topped.

circulator. In addition, on trials E and F, the main steam pipes were kept filled with steam at the boiler pressures given.

lectric-light engine and one refrigerating engine.

† Estimated from previous column.

TABLE C.

Blowing engine. One steam cylinder, 9¼ inches diameter, 9 inches stroke.		Electric light engine. Steam cylinders, high pressure, 7½ inches diameter, 9 inches stroke, and low pressure, 15 inches diameter, 9 inches stroke.			Auxiliary circulating pump. One steam cylinder, 7 inches diameter, 7 inches stroke.	Refrigerating engine. Steam cylinders, high pressure, 5½ inches diameter, low pressure, 10⅜ inches, stroke 12 inches.	Feed engine. One steam cylinder, 16¼ inches diameter, 18 inches stroke.	Evaporator primary steam. Pressure per sq. in.
Revolutions per minute.	Pressure of air, pounds per sq. in.	Revolutions.	Volts.	Ampères.	Revolutions per minute.	Revolutions.		
96.1	6.6	309	79.9	599.3	85.2	...	From 1 to 3 double strokes per minute.	147.5
80.4	6	...	...	...	94.6	...		102.0
71.8	5	...	...	...	82.9	...		...
72.3	5	...	...	...	81.3	...		...
73.0	5	...	...	...	82.25	...		...
73.2	5	...	...	...	70.6	...		...
73.6	5	300.7	80	600	92.8	...		112.7
73.8	5	304	80	600	85.7	...		...
73.6	5	309.6	80	600	81.2	...		112
73.0	5	315	80	600	83.5	...		...
73.8	5	320	80	600	82.3	...		113.1
73.87	5	320	80	600	81.8	...		112.1
100	8	315	80	600	119.2	118.2		...

AUXILIARY MACHINERY IN USE ON THE SEVERAL TRIA

On trials A, G, I, K and L.—One main feed pump, one blowing engine, one auxiliary circulator, one electric-light engine, two distill

On trial B.—Same as A, G, I, K, L, with the exception of electric-light engine being stopped.

On trials C, D, E and F.—One main feed pump, one blowing engine and one auxiliary circulator. In addition, on trials E and F, th

On trials H and J.—Same as G, except that the evaporators were not in use.

On trial M.—One main feed pump, one blowing engine, one auxiliary circulator, one electric-light engine and one refrigerating engin

* Measured water made per hour.

sure per sq. in.	Distiller pumps. One steam cylinder, 6 inches diameter, 7 inches stroke.		Water made, gallons per hour.*	Total water made, including coil drain, tons per day.†	Pounds of water evaporated per pound of coal.	Water pumped from feed tank, pounds per hour.	Coal Consumption.		Distinguishing letter of trial.	Remarks.
	Revolutions.						Pounds per hour.	Tons per day.		
	Starboard.	Port.								
7.5	78.1	83.8	247.6	59.6	Not taken	Not taken	975	10.4	A	The whole of the coal used was carefully weighed on all the trials.
2.0	83.1	95.6	170.4	41.8	Do.	Do.	625	6.6	B	No fires were cleaned during the trials.
..	...	...	...	...	Do.	Do.	250	2.6	C	As far as possible, the condition of the fires at the end of the trial was the same as at the beginning, but there was some slight variation in this, owing to the short time available between some of the trials for cleaning and getting up the fires afterwards.
..	...	...	...	...	Do.	Do.	237.5	2.5	D	
..	...	...	...	...	Do.	Do.	525	5.6	E	
..	...	...	...	...	Do.	Do.	312.5	3.3	F	
2.7	79.7	78.4	236.1	56.9	8.79	7,255.0	825	8.8	G	
..	...	...	...	...	7.23	4,160.0	575	6.1	H	
2	78.7	79.1	198.6	47.8	10.56	7,001.0	662.5	7.09	I	
..	...	...	...	...	10.21	3,710.0	362.5	3.88	J	
3.1	79.0	79.0	203.8	49.05	8.96	6,947.5	775	8.3	K	
2.1	78.0	79.0	215.8	52.02	9.10	7,435.0	812.5	8.7	L	
..	...	...	...	...	...	...	350	3.75	M	

RIALS.

tiller pumps and two evaporators working compound.

', the main steam pipes were kept filled with steam at the boiler pressures given.

gine.

† Estimated from previous column.

of 30 pounds per electric horse power per hour and an electric horse power of 64, with an evaporation in the boiler of 9 pounds of water per pound of coal, the coal equivalent of the electric-light engine works out to 2.4 tons per day. The difference between C and A gives 7.8 tons as the coal expended on electric light and distilling, and deducting 2.4 for electric light, we have 5.4 tons for making 59.69 tons of water, or 11.1 tons of water per ton of coal. Again, the difference between C and B = 4 tons, which was expended in distilling 41 tons of water, or 10.25 tons of water per ton of coal, a result agreeing well with the figure previously given, the difference pointing probably to a slight reduction in efficiency due to the scale formed on evaporator coils.

In conclusion, it is submitted the trials carried out in the *Diadem*, which have been neither few in number nor generally short in duration, have shown that the engines and boilers are economical and efficient for warship service, and the fitting of the economizer to the boilers has been attended with beneficial results.

Discussion.

Mr. A. E. Seaton opened the discussion on this paper. He said that the subject of the Belleville boiler was rather a prickly one. The Admiralty authorities had been subject to some very severe criticism; but Sir John Durston had, in spite of this, always treated the matter in a free and liberal spirit, giving information fully and receiving hostile criticism goodhumoredly. One point that would strike members was the heavy coal consumption of the auxiliary engines in warships. Particulars of certain trials were contained in the paper. The author had said that the coal consumption for auxiliary purposes was considered abnormally high, and the opportunity was taken to test the quantity of steam or coal required for such purposes only by a series of trials with the main engines at rest and the ship in the basin. The trials were made with two boilers in use, and were each of eight hours duration, and the quantity of coal burnt per day, as shown by a Table given in the paper, varied from 2.5 to 10.4 tons for auxiliary purposes. Naturally, with this large variation, the same number of auxiliary engines were not always in use on all the trials.

Mr. Seaton, referring to the above figures, said it was found also in the mercantile marine that the consumption of steam by auxiliary engines was very heavy. He would refer to the Weir feed pumps. These were most popular with sea-going engineers; they were simple and efficient, and as a sure instrument for supplying water to boilers they were probably unequaled. Unfortunately, they were probably unequaled in another respect also, viz: in the consumption of steam for the work they did. The speaker knew it was impossible to have one's cake and eat it too; and, doubtless, if simplicity and absolute certainty were to be considered before everything, some sacrifice of fuel must be made.

In another assemblage it was customary to lay every defect that occurred in Her Majesty's ships at the door of the Belleville boiler. Members of the Institution would not be likely to err in this respect. He had had some experience with these boilers in the *Arrogant*, a vessel containing Belleville boilers on the old plan, without economizers. The working was excellent, and he was especially struck with the free-and-easy manner with which the firemen and engineers treated the boilers; the consumption of coal, however, was somewhat alarming, and on inquiry he found that to be due largely to the auxiliary machinery. He would suggest it would be a most profitable direction to which members might turn their attention, if they would exercise their ingenuity in inventing a feed pump which would act as surely as the Weir pump, but in which the consumption of steam would be more satisfactory.

Another source of loss to which he would call attention would be the radiation of heat from the boilers, &c. The days of felt covering were, of course, gone; asbestos compositions were good as non-conductors, but they soon began to lose their efficiency through non-contact with the surface they were intended to protect. The metallic bodies also that held the coating in position were conductors of heat, and reduced its efficiency to a considerable extent. Mr. Seaton had been trying some experiments, and found it really remarkable how heat passed away through a slight metal attachment. The steam pressure used in water-tube boilers was necessarily high, and that aggravated the difficulty.

He looked on the reducing valve as the steadier and a means of superheating; if superheating were used, it was necessary to have some means of control. He thought the economizer was the great thing needed to make the Belleville boiler a success. Those who had had experience knew how hot the base of the funnel became, and also how apt there was to be flame coming

out at the chimney top. The economizer cured both these evils, and at the same time reduced the consumption of fuel. He thought not sufficient attention was paid to the fact that efficiency in evaporation of water depends largely on the difference of temperature between the water and the furnace gases. Mr. Yarrow, by a certain experiment he had shown him, had brought this forcibly to his mind.

Mr. Allen, of Bedford, said he had not intended to speak on the paper, but, as the auxiliary engines were referred to, he wished to make a few remarks on the subject. Experiments had been made at the works of his firm bearing on this matter, when electric-light engines were first introduced on shipboard some years ago. The steam used was at the rate of 140 pounds per electrical horse power per hour. At the present time it had been brought down to 27 pounds per electrical horse power. Many of the auxiliary engines suffered from being too large for the work they had to do. For instance, the *Diadem's* circulating pumps had to be of sufficient size to be used for pumping water out of the bilge in case of leakage. That necessitated them working ordinarily at only one-fifth their full power, and, naturally, they were very wasteful of steam for the work they had to do under these circumstances. Again, the fan engines were said to use 50 pounds of steam per indicated horse power; they were simple engines cutting off at half stroke, and if the cylinders could be reduced to the work they had to do under ordinary conditions, an immense gain would be made in economy. In regard to reducing valves, he was convinced that there was a gain. For instance, with 150 pounds of steam, with the reducing valve in use, the same effect was obtained as at 220 pounds without the reducing valve.

Mr. Macfarlane Gray said that, in regard to the economizer, efficiency did not depend so restrictedly to the difference in temperature between the gases and the water as many seemed to think. He had held the opinion many years ago that efficiency of heating surface did depend solely on this difference. Two hundred years ago this year the patent was taken out for Savary's boiler, which consisted of a heater and evaporator, and that was just what we had come back to. Some facts that came out in connection with the use of Halpin's heat-storage system bore on this matter. Steam generated during the day imparted its heat to water contained in large cylinders of water, and this water, in its turn, supplied feed for the boilers when additional

steam was required. In order to test what was lost by this system, observations were taken, the result of which came out that there was not only no loss, but a 16 per cent. gain in fuel economy. This was looked on as impossible, and it was concluded that there must have been an error in the observations. The trials were therefore repeated, but with the same result. The thing was so surprising that Professor Unwin was called in. He made some careful trials and found that the economy was 19 per cent.; the heat was really taken out of the smoke, the economy being due to the increased efficiency of the heating surface of the boiler, owing to the feed water being closely on the point of evaporation. It should be laid down as a principle that no heat but the latent heat of evaporation should be communicated to water through heating surface in the boiler. Professor Elliott, of Cardiff, had written a paper pointing this fact out, and Mr. Seaton had already brought it forward some years ago.

Mr. Frederick Sawyer wished to say a few words on the subject of distilling machinery. Sir John Durston had said that 11 tons of water were distilled with 1 ton of coal, but it was easy to obtain a far better result than this. He had constructed multiple-effect evaporators, in which he had obtained 35 tons of distilled water for a ton of coal. He was aware that it might be objected that the additional weight of this form of evaporator might be a drawback on shipboard, but he thought that the saving in coal on a voyage of any length would far more than counterbalance the drawback of additional weight in the apparatus used. In regard to what Mr. Gray had said, he had been for years carrying out the principles laid down by that speaker.

Mr. Yarrow asked whether, in consideration of the large loss of efficiency due to the auxiliary machinery, it would not be possible to pass the exhaust from those engines to the low-pressure or larger cylinders of the main engines.

Sir John Durston, in replying to the discussion, said that the object he had in writing the paper and giving details of the experiment, had been to a certain extent fulfilled. He would like, however, to have had more extended discussion on the paper, and to have received the help afforded by the criticism of a larger number of members. It was quite true, as Mr. Allen had said, that the consumption of steam in the electric-light engines had been reduced from 140 pounds per electrical horse power per hour down to 27 pounds; that was satisfactory, but the task was ren-

dered easier, because it was possible to compound the electric-light engines. With other auxiliary machinery, however, this could not be carried out, for various reasons, one of which being, in regard to machinery in the engine room, want of space; of course, it would be impossible to compound the steering engine.

To reduce radiation they had been making a large number of experiments, in order to find out the best covering composition; the results of these were of interest, and would probably be communicated later. Mr. Sawyer was quite right in saying that 35 tons of water could be distilled with a ton of coal; that figure confirmed experiments he had himself made, but in order to reach this result additional weight and space had to be afforded on board ship. It was a question of balance and advantages and disadvantages, which system was desirable.

Returning to the question of auxiliary engines, Sir John Durston said that for the purpose of war vessels it was desirable to use simple engines where necessary, and supply them with steam at pressures appropriate to their needs. In regard to passing the exhaust from these engines to the low-pressure cylinders of the main engines, the difficulty of handling the ship stood in the way. It must be understood that a war vessel was not designed to make a voyage from point to point with lowest fuel consumption possible, otherwise the arrangements would often be very different; but they had to think of the ultimate use of the ship when the engines would be stopped and started or reversed with the greatest promptitude and without warning; to use exhaust steam from auxiliaries in the main engine might interfere with this paramount duty. His present view of the matter was that it would be most advantageous to use the heat in the exhaust steam from auxiliaries in raising the temperature of the feed water.

DEDICATION OF A BRONZE BUST OF CHIEF ENGINEER ISHERWOOD, U. S. NAVY.

During the winter of '97 and '98, a fund was subscribed by the friends and admirers of Chief Engineer Isherwood for the purchase of a bronze bust, which was modeled by Dunbar and cast by Bureau Brothers. The subscribers included not only officers of the Engineer Corps of the Navy but many distinguished engineers in civil life, some of whom were formerly naval officers. The names of a number of them are given in an appendix. The business management of the affair was in the hands of Chief Engineer Geo. W. Baird, U. S. N., while Messrs. Chas. H. Loring, J. B. Houston, Geo. W. Magee, John C. Kafer and Clark Fisher acted as an art committee to determine the excellence of the work. It is gratifying to state that Mr. Dunbar's work is accounted a fine effort, and that the features of the famous "War Chief of Bureau" are faithfully portrayed.

It was felt by those having the affair in charge that it would be a suitable and highly enjoyable occasion to celebrate the dedication of the statue by a banquet, at which as many as possible of Mr. Isherwood's contemporaries should be present and at which he would be the guest of honor.

The banquet took place at the Bellevue Hotel, in Philadelphia, on the 2d of April, when the bust was unveiled and a series of tributes paid to Mr. Isherwood, which are not only admirable for their testimony to the splendid pioneer work done by him in engineering science and for the appreciation of his eminence as an engineer, but are worthy of preservation for the benefit of younger American engineers, as placing in succinct form the account of Mr. Isherwood's work both as a scientist and as the administrative head of the engineering department of our Navy during the great stress of the Civil war.

A touching feature of the occasion was the presence of the venerable Charles H. Haswell, the nestor of the profession, who,

as the first engineer of the American Navy, its first chief engineer and first Engineer-in-Chief, practically moulded the Engineer Corps as it exists to-day. The tribute of this venerable and accomplished gentleman, now almost ninety years of age, must have been the most touching to Mr. Isherwood of all those rendered.

At the request of those present, Chief Engineer Baird presided, and, when an elaborate menu had been discussed and the coffee and cigars had arrived, introduced, in a few well-chosen and highly complimentary remarks, the orator of the occasion, Dr. Robert H. Thurston, who spoke as follows:

ADDRESS BY DR. ROBERT H. THURSTON, DIRECTOR OF SIBLEY COLLEGE, CORNELL UNIVERSITY; FORMERLY OF THE U. S. NAVAL ENGINEER CORPS.

GENTLEMEN: Allow me first to acknowledge, cordially and gratefully, the compliment paid me, in my selection as the orator on so important and so notable an occasion, by my old friends and colleagues of the Engineer Corps. It is indeed, an extraordinary and a memorable occasion, and there is good reason for the rare interest which I feel in the proceedings of this evening. The distinguished guest of the evening has been, for many years, a friend and professional colleague and his admirable personal qualities have been constantly visible. As a member of the Corps and in official relations, his work, public and private, official and routine, and scientific, has been familiar. As a member of the faculties of the Naval Academy, of the Stevens Institute of Technology and as the head of Sibley College, Cornell University, as well as in a continuous practice, professional and other, for now a full generation, I have had occasion to study the work of this pioneer in the application of scientific method to research in the applied sciences of engineering, and thus have learned something of their extent, their originality and their great interest and importance.

As a friend, I esteem it a rare privilege to take this venerable, but still youthful-looking colleague of those days of storm and stress, by the hand and to express to him the pleasure that all his friends feel in seeing him here, in health, strength and high spirits, renewing his youth. As a colleague of those trying days

of hard work, of professional pressure and of external and internal strife for the right and for all that makes for the right, it is an even greater privilege and pleasure to be able to meet him, in the fullness of his years, with a long and a useful and a fruitful life on the record, with his victories won, his fame attained, his judgment vindicated and his rewards secure, and to be permitted to give him assurance that all his old colleagues and friends recognize and rejoice in his success and his triumph. As a member of the corps it is a duty, as well as a privilege, to seize the opportunity to greet this always reliable champion of the admirable body of officers whose representative he so long was officially, and whose best interests he has always kept in view and effectively promoted. As a member of the engineering profession also, it is no less a duty to acknowledge on this occasion the indebtedness of the profession to the man who, for the first time, made scientific work subsidiary to engineering in such manner as to justify the claim of the wisemen of the later times, that engineering has come to be, not simply a learned profession, but, as the distinguished president of a famous and noble university has said, the most learned of professions. Personal friends, members of the United States Naval Engineer Corps, men of science, engineers of all departments of the profession and of science and the world at large;—all have good reason to tender their acknowledgments to this man whose work has done so much for all.

The occasion is a notable one, and is thus memorable both in relation to the individual and in its bearing upon the progress of professional and national welfare. Our guest is a man of achievement. With rare talent, with extraordinary industry, with marvelous endurance, his personal character, his professional standing, his position before the world, and his connecting art, industry and science, present those natural and mutually intimate component and resultant relations that distinguish all such cases. He is one of the notable men of the century, of that century which, in science and in engineering, and in the progress of the naval arts, has been marked off by historians and by economists as one of sudden and marvelous advancement in the sciences, in all

arts and in all that makes civilization. He is one of those to whom this century and this generation owe their noblest achievements. The growth of the steam engine, from the days of James Watt to those of Melville, the progress of steam engineering, of the development of motive power, lies at the foundation of all existing prosperity, and it is the power of steam that has raised civilization from the lower levels of earlier days and so promptly and startlingly placed it upon the altitude of our times. It is this wonderful power, or possibly some even more efficient heat motor, it is safe to say, that will continue to compel advancement at this dizzy speed toward still higher and better things. It is in this department of combined science and art, of the applied sciences of engineering, that Commodore Isherwood, as Engineer-in-Chief of the United States Navy, took his place and performed so splendid a work.

When steam furnished a means of converting the latent energy of fuel into the kinetic energy needed for the performance of all useful work a new era dawned for the world; when Watt applied the methods of science to the investigation of the thermal wastes of the steam engine a new era was begun in the history of engineering; when Isherwood showed the bearing of Watt's discovery upon the applied economics of steam engineering, he initiated a new era in that department of professional work. It was the application of scientific method and the use of the apparatus of science in the exhibition of the relation of the wastes of the steam engine to the limitations of thermo-dynamic theory that constitute the claim of our guest to fame and professional honors. Watt—in fact, Smeaton before Watt—showed that such wastes occurred; other investigators took each his step in the same direction, and the work of Smeaton and of Watt, of Clark and of Hirn, of Leloutre and of Hallauer—Hirn's colleagues, at once disciples and teachers—cannot be too highly appreciated or too widely known. But the complete investigation of the effect of initial condensation of steam in the cylinder of the engine, with its variations with varying expansions and under varying conditions otherwise, with proof of its absolute limitation of the effective utilization of the principle of expansion, was the work

of Isherwood, and it was the dissemination of this knowledge throughout the world, promoted largely by hostile criticism, that first brought constructors and designers of the steam engine to an understanding of the finance of the steam engine as thus subject to limitation. Smeaton and Watt, Sickles and Corliss, and Isherwood, Porter and our Chiefs of Bureau, from Copeland and Haswell to our own time, took part in this gradual clearing away of the misconceptions of the earlier days. All such progress was the outcome of the gradual introduction of scientific method into engineering practice, to the more and more complete alliance of science with art, in engineering.

The development of scientific methods, and the more and more general employment of research in engineering, have been the characteristics of the time in the advancement of engineering. This method and this novel application of the processes of the physical science have been the characteristics of the work of Isherwood. Their influence upon the progress of the world has been commensurate with their influence upon the profession itself. Within the half century the profession has come to be recognized as—not a simple vocation, a trade, having only a practical knowledge of an art as its basis—actually a profession, not only learned, but having a place with, if not above, the professions of even the surgical branch of medicine, above the legal profession; in this respect, we may claim with no disrespect to that cloth, even above the clerical profession; for it is raised upon a grand foundation of scientifically established positive knowledge. Our professional schools are now unsurpassed among professional schools of whatever sort, in their demands upon the candidate for admission, and especially in exacting more, and more difficult, work than is customary elsewhere, and in making the diploma representative of an extraordinary amount of work in the mathematical and physical sciences, in the special applied sciences of engineering and in their formal and practical applications in professional work.

Benjamin Franklin Isherwood—how fortunate the cognomen!—illustrates, in his whole professional career the fruitfulness of scientific work in engineering. By such illustration he has

made himself competent, and has acquired the right, to command our admiration and our highest honors. Let us study, in some detail the outline of his life and works. The facts presented are authentic, having been obtained, in part, by cross-examination of their subject and largely through the zealous and tactful exertions of the toast-master of the evening, Chief Engineer George W. Baird.

On an occasion like this, a brief sketch of the most salient features of his professional education and career seems to be appropriate, and certainly will be of interest.

Chief Engineer Isherwood has been most fortunate in his day and generation. He began his professional life at a very early age, just at the time the first railroad was completed in his native State, New York, and just at the time steam engineering fairly commenced by the construction of the large passenger steamboats for the Hudson River. His professional course ran parallel with the development of Steam Engineering in the United States, and ends with it at probably not far from the highest point it can ever reach. It thus spans the whole of what may be termed a great era not only in engineering but in civilization, for the latter depends wholly on industrial causes and is determined by them both in direction and intensity, and Steam Engineering is the greatest of all industrial causes the world has ever known and perhaps ever will know.

The early preceptors of Chief Engineer Isherwood at the Albany Academy, under the supervision of the Regents of the University, were Dr. Henry, later the celebrated Secretary of the Smithsonian Institute, and Dr. Ten Eyck, quite as able though not so well known. These distinguished scientists were his instructors in mathematics and natural philosophy, and their interest in him ended only with their lives, so highly did they appreciate his character and abilities. The Principal of the Albany Academy, Dr. T. Romeyn Beck, was his instructor in Belles Lettres and in Physical Science. Afterwards, Chief Engineer Isherwood was employed as draughtsman in the locomotive shops of the then Utica and Schenectady Railroad, a railroad on whose construction he had been employed as a civil engineer

under Wm. C. Young, one of the most prominent civil engineers of that day, the immediate superior of Chief Engineer Isherwood being the distinguished English civil engineer, Wm. Lake, afterwards largely employed by the Canadian Government on the design and construction of the Rideau Canal and Lakes Improvement.

After leaving the Utica and Schenectady Railroad, on its completion, he was employed as a civil engineer in the construction of the Croton Aqueduct for supplying New York city with potable water, under the well-known John B. Jervis, and on the completion of that work he was employed again as a civil engineer on the New York and Erie Railroad. He was next employed on a lighthouse survey by the Treasury Department, after which he entered the corps of Naval Engineers, then in an inchoate state, but rapidly crystallizing under the great professional and executive ability of its first real Engineer-in-Chief, Charles H. Haswell, undoubtedly the best scientific and practical steam engineer of his day. For some time after entering the corps, Chief Engineer Isherwood was detailed to the Superintendent of Lighthouses, under whom he designed and erected some lighthouses, and was sent to Paris to have there constructed a lenticular lighting apparatus of his own invention, afterwards erected by him in the United States. He was also extensively employed in making examinations, surveys, repairs and alterations of lighthouses. He served during the Mexican war on board the original steamship *Princeton*, and afterwards as senior engineer of the *Spitfire*, taking part in all the actions in which the latter was engaged against the Gulf ports of Mexico, and particularly against Vera Cruz, during the siege of which by the army the *Spitfire* alone attacked the castle of San Juan d' Ulloa. Later he served as chief engineer of the steam frigate *San Jacinto* during a cruise of over three years on the Asiatic station.

When not attached to any vessel, he was employed by the Navy Department on shore service, but whether ashore or afloat, he continued a systematic course of experiments as far as the opportunities of those days would allow, on all the various subjects incidental to steam engineering. The results of many of

these experiments were published and attracted great attention; the results of a still greater number, however, have never been made public. He was always selected by the Navy Department for president of whatever boards were ordered for experimenting on any engineering subject.

Chief Engineer Isherwood had long investigated the expansion of steam in the working cylinders of steam engines, both theoretically and experimentally, and had observed that with the steam pressures habitually employed in those days, rarely exceeding 20 pounds per square inch above the atmosphere for marine condensing engines, there was a great disaccord between the theoretical and the experimental results. He also well understood that the problem was a purely practical one, and not to be solved, or the solution even aided, by mathematical deductions based on conditions which were not the conditions of Nature, but solely by experiment. He fully comprehended that the enormous difference between the abstract theoretical conclusions and the practical facts was due to the interchange of heat between the steam and the metal of the cylinder, and to the fact that steam was a vapor governed by laws wholly different from those applicable to ideal gases; and to the further fact that the product of the mass of the metal into its mean specific heat was enormously greater than the product of the mass of steam it enveloped into the mean specific heat of that steam. Further, he comprehended the immense influence which these facts must have upon the economy of the steam, let the latter be used with or without expansion, and particularly upon the greater economic gain by using steam with greater measures of expansion, the effects of these facts all tending to diminish, and very largely diminish, the theoretical gain due to assumptions of the Mariotte law, and that of Gay Lussac, which are only applicable to ideal gases, and only to them under ideal conditions. He distinctly pointed out the great influence which the waste space at the end of the cylinder had upon the economy due abstractly to expansion; that influence becoming more and more disastrous as the measure of expansion became greater and greater; also the great influence which the friction of the unloaded engine and

of its load, and the equally great influence of the back pressure against the piston, had upon the economy of steam used with different measures of expansion; the economy due to increased expansion being very considerably reduced by all these causes, every one of which operated the more potently the greater the measure of the expansion with which the steam was used. The final result was that the economy, thermodynamically predicable upon increasing the expansion of the steam, rapidly diminished practically, until a measure of expansion was soon reached at which the prejudicial practical influences equaled the theoretically beneficial ones, beyond which further expansion involved a loss instead of a gain in economy.

The particular measure of expansion at which this equality of the effects of opposing causes would occur depended, as an obvious corollary, on the pressure of the steam used. The higher the pressure for a given measure of expansion the less would be the disproportion between the quantity of heat in the steam and the quantity of heat required to produce a given variation of temperature in the metal of the cylinder. Also, the higher the pressure the less becomes the effect of the frictions of the unloaded engine and of the load of the engine, and the less becomes the influence of the back pressure. But, under all conditions, there was a point beyond which the further expansion of steam involved an economic loss instead of gain, and under all circumstances the gain realizable was small in comparison with the gain that should be obtained according to thermodynamic computation. This is what Isherwood deduced, about forty years ago, from a consideration of the antagonistic influences which must be taken into account in connection with the expansion of steam, and he proved these to be facts by a series of original experiments made on engines, small and large, as constructed at that period, and working under the actual conditions then employed.

The originality of these views was proven by the general dissent with which the engineering world received them. They were contested by many, while few openly accepted them; and Chief Engineer Isherwood had to endure a storm of obloquy and denunciation, of vilification and contumely, from those whose

ignorance was exposed, whose pride was hurt, or whose profits were menaced by the new revelation he had given to the engineering world. Like all reformers, he was misapprehended and misrepresented. Opinions were attributed to him which he had never expressed, and he was accused of controverting principles which he had never denied. The most cursory examination of the engineering journals of those days will prove that these remarks are well within the truth. The fact that we are assembled to-night to express our high appreciation of the talent of the subject of these erroneous and absurd criticisms proves how utterly unfounded they were.

The observation that a large portion of the total weight of steam entering a working cylinder is liquefied by the interaction of the heat of the steam with the metal of the cylinder, and that, other things equal, this fraction increases with increase in the measure of expansion with which the steam is used, and the proof that the failure of expanded steam in working cylinders to give the economy that should from the Mariotte law follow the increase of expansion is due to the fact that increased expansion is accompanied by increased steam liquefaction, a discovery of the highest importance, were early made by Chief Engineer Isherwood; and these have been the clues for all succeeding investigations by whomsoever made. He did not publish these results as suggestions or as inferences. He proved the facts experimentally by an extensive series of experiments, made by order of the Navy Department, on the engines of the United States steamer *Michigan*. These were the *first* experiments ever thus made on the subject, and they were given, *in extenso*, in a report which may be considered a model for engineering literature. That report initiated investigations on abstruse points of steam engineering, which have continued to the present time and must continue indefinitely; for the phenomena of nature are infinite in number and difficult in exposition.

Chief Engineer Isherwood was the first to compare accurately the weight of feed water pumped into the boiler with the weight of steam shown by the indicator in the cylinder at different points of cut-off, throughout the stroke of the piston, and thus to estab-

lish beyond question not only the fact of cylinder liquefaction of steam qualitatively, but also quantitatively. This knowledge is the key to the enigma of the principal phenomena attending the use of steam in working cylinders. He was the first to make a complete series of experiments on the expansion of steam, employing the same engine and varying the measure of expansion at short intervals, extending from a very large measure of expansion to nearly full stroke. He furnished in his reports complete descriptions of machinery, method and results. When these facts and deductions were given to the world, no one claimed to have earlier discovered them; no one even asserted they were correct; but, on the contrary, they were met with general disbelief, and the discoverer received vituperation instead of praise. No better proof is needed either of the originality of the discoveries or of the completeness of their exposition. The numerous professional experiments and writings of Chief Engineer Isherwood may be said to have marked a most important era in the progress of steam engineering, and they extended to every principle and to all detail. Nothing was too small to be overlooked, nothing too large to be undertaken.

Immediately after the outbreak of the war of the rebellion, Chief Engineer Isherwood was appointed Engineer-in-Chief of the Navy; and very soon afterwards, so important were his services considered by the administration that the Bureau of Steam Engineering was created in the Navy Department, for him, by Congress. He became its first Chief, a position which he held during the terms of President Lincoln, by whom he was appointed, and of President Johnson, by whom he was reappointed, a period of about eight consecutive years. The war period was one of unexampled activity in the Navy Department. Fleets were improvised from merchant steamers; new fleets were designed and constructed of various types and sizes of vessels. Engineers were obtained and organized for them. The entire steam engineering plant of the country, both in private establishments and in the Navy Yards, was loaded with work, a large proportion of which was designed by the Chief of the new Bureau of Steam Engineering, who assumed absolute powers in his own specialty, and was

the dominant factor in a great deal of what was done in other directions, particularly in the design of the hulls as well as of the machinery of the new war vessels. The Secretary of the Navy had unfaltering confidence in the ability, integrity, activity and energy of the Chief of the new Bureau, a confidence which he retained and expressed to the last days of his life.

Chief Engineer Isherwood had all too little assistance in his great work, which he performed with an extremely small staff. Notwithstanding these demands, he found time to originate and prosecute extensive series of experiments on almost every problem of marine steam engineering, and to write and publish two large quarto volumes on the same subjects. The minutest subject did not escape him; he determined the relative and absolute heat conductivities of the commercial metals, wrought iron, cast iron, brass and copper, under the actual conditions of practice in boilers and surface condensers; and he also determined the relative and absolute heat conductivities of cow-hair felt of different thicknesses.

The necessity for new boilers in a great many of the steamers purchased during the war enabled the Chief of the Bureau of Steam Engineering to design them for experimental as well as for practical purposes; so that he determined the relative and absolute economic vaporizations and with different fuels, of various types of boilers and of various proportions, all on the largest scale of practice. Experiments on natural and forced draft were made. In fact, every subject germane to steam engineering was investigated in its practical applications; and, more than all, the objects, methods and results, were given to the world, as far as possible, in reports of high literary character. This knowledge was disseminated with absolute liberality of spirit. There were no small attempts to conceal or to make the world believe something of importance had been discovered but withheld from it for the benefit of the discoverer or of the Navy Department. Chief Engineer Isherwood was free from this vice of petty minds, and he was absolutely fearless of consequences. His position of Chief of the Bureau of Steam Engineering gave him a wide field, every portion of which was well cultivated.

He not only experimented himself, but he encouraged other members of his corps to do the same, and was always ready to support them with advice, means and opportunities.

Chief Engineer Isherwood always held that, in physical problems, no theoretical or mathematical investigation was conclusive until it had been confirmed by extensive experiment under the conditions of practice. Thus he was often in opposition to accepted theories, but never to natural laws as revealed by observation. Whenever it was possible to make experiments, he made them. He erected *his* theories upon that foundation. His object was simply the truth, and his appeal was always to nature; he ever held that if the question be properly put to her, she will give an infallible answer; and that no other authority could.

In the production of fast cruisers, which has since become one of the distinguishing features of the new or modern navies of the world, Chief Engineer Isherwood was the pioneer. He invented this class of vessel and produced it against the most violent opposition. He had to deal with wooden hulls and comparatively small displacements (not exceeding about 4,000 tons). He was virtually the designer of their hulls, and the machinery was made from his working drawings. But, notwithstanding their small displacements, and the fact that he had to use the simple marine engine with boiler pressures not exceeding 40 pounds per square inch, and notwithstanding that his vessels were provided with full sail power, he succeeded in giving them a sustained sea speed of 16⅔ knots under steam alone; a speed never since equaled with vessels of the same displacement at sea, and which was greatly in excess of the speed that could be sustained at sea by any vessel at that time, whether merchant or naval. In naval annals the name of *Wampanoag*, the type vessel of that class, has become historical.

When the war ended, the country was in possession of a magnificent fleet of cruising steamers, having full sail-power in conjunction with full steam-power, and they were the only instances in which this difficult problem has been completely solved. They were remarkable for speed, for nautical qualities, and for the

economy of their steam-power, relatively to the type of machinery then in use. These vessels were the creation of Chief Engineer Isherwood under the greatest difficulties and against a violent opposition, and their models and proportions, though not approved by the professional naval constructors when the vessels were built, were heartily endorsed when their great qualities were demonstrated by experience. The constructors remained to the last, not only the admirers of Chief Engineer Isherwood professionally, but his firm personal friends as well.

Naturally, a man of Chief Engineer Isherwood's character and attainments could not avoid making enemies during the eight years of his professional career in the Navy Department. That period embraced the war, during which the vast operations and expenditures of the Navy Department made it the target for the virulent attacks of all kinds of inventors, pretenders, contractors, frauds, humbugs and incompetents, professional and otherwise, of all kinds, many of whom were backed by strong political influence. The disappointments of ambition and of greed and the pangs of injured vanity and pride were focussed upon the most conspicuous person wielding power in that Department, who was quite indifferent to their attacks, careless as to whether he was employed in the Department or elsewhere, and only solicitous to exert his abilities on the side of truth and honesty and for the advantage of the Navy.

After leaving the bureau, he became the Chief Engineer of the Mare Island Navy Yard, California. He there made a most valuable series of experiments on screw propellers and on the calorific values of the coals of the Pacific coast.

After leaving the navy yard, he was sent abroad with Chief Engineer Zeller on a commission to examine the dockyards, vessels, etc., of the navies of Western Europe. When he returned he became the president of the Experimental Board under the Bureau of Steam Engineering, which position he held up to the time of his retirement, with the rank of commodore, at the legal age of sixty-two years—fourteen years ago. During these fourteen years his time has been actively devoted to professional pursuits, and the numerous, varied and important papers he has

published in that period have given him a high reputation as an engineer with the engineers of all civilized countries, and as a scientist with their scientists. He has, also, most efficiently protected the Corps, which owes its present high position and great development very largely to him, and on more than one occasion he has saved from destruction the Bureau he created.

This short and very inadequate sketch of a long, eventful and distinguished life cannot be more fittingly closed than in the elegant and appropriate language of Chief Engineer Baird, in his circular proposing that the Corps of Naval Engineers have a bronze bust of Chief Engineer Isherwood executed as a memorial of the consideration in which they hold and ever have held him.

"Almost every profession has honored its famous leaders by some enduring memorial. In our profession Benjamin Franklin Isherwood stands pre-eminent. He was the first American naval engineer who made an international reputation, and he has now passed from active work to retirement with nothing but his splendid record and the respect of those who know and appreciate it to keep alive his memory.

"While the rest of the engineering world had run mad with misunderstanding and misapplication of physical laws, he had the genius to detect, and the practical skill and courage to demonstrate their error. His experiments still prove models for all engineers and a mine of information for students. He was, in fact, the first American Naval Engineer whose work was known and valued throughout the domain of engineering. We should therefore count it a duty as well as a pleasure to join in a memorial which shall recall him to the engineers of the future when we, who have known him well, are gone."

In closing the address, the speaker called upon the friends, the colleagues, the admirers present of the sturdy friend, the loyal colleague, the patriotic representative of the United States Naval Engineer Corps, the promoter of every best interest of the navy and of our country, and the tardily famous investigator—Benjamin Franklin Isherwood—rising, to drink to the health of the guest, wishing him length of days, good health to

the end, and assuring him his memory will remain in the hearts and minds of later generations of his profession, more enduring than the bronze which was now unveiled.

The toast was properly responded to and the bust was unveiled.

CHIEF ENGINEER B. F. ISHERWOOD, U. S. NAVY.

With great embarassment I attempt a reply to the too flattering address in which Dr. Thurston, with all the partiality of an old friend, has just described the professional career which has received the high commendation of your sanction by its commemoration with a bust preserving my features in monumental bronze; and, what is of far greater importance in my estimation, recording the fact that I have been able to obtain this appreciation as an engineer and this esteem as a man from such engineers and such men as I see around me. During the little that may remain to me of life, I shall always think better of myself in both capacities, and the world, I am sure, will think better of me too. No one could descend to the future with a higher indorsement; and my hope is that I may have merited some small portion of the commendation which has been so generously and so lavishly bestowed upon me.

In the twilight of life, when its passions are cooling, when its ambitions are sinking to their true level, and when the nothingness of its efforts are becoming clearly certain, the one gratification that remains unchanging and imperishable is the free approbation given by those who marched side by side with us through its sunshine and its shadow, and the noblest of epitaphs is the one in which they record that something has been done worthy of their praise.

To very few is given during life to receive a disinterested testimonial from their peers expressing satisfaction with their character and achievements. Generally, that expression, if it ever comes, comes too late, long after its object has passed forever beyond the reach of approbation or of censure; I therefore count myself among the very fortunate who have received, while still living, an ovation like this, that tells me not only of the regard in which my compeers hold me, but also of their

desire to express it publicly while such expression can give me the pleasure of its knowledge. It has thus a double value, for while it declares an abstract appreciation, the declaration is made at a time when it is also an evidence of personal friendship. I accept it in this double sense with gratitude and emotion; and as long as memory remains, the events of this evening will remain vividly in it as the most delightful ones of my external life.

I return my fervent thanks to the donors of this enduring testimonial for the distinguished honor they have bestowed upon me. It is the brightest golden thread inwoven with the tissue of my life. It is conferred by those who know me well—by my professional and by my personal associates; and if it marks my passage from active life, it also intensifies my feelings of regard for them, which will end only when life itself is ended.

CHIEF ENGINEER WM. H. SHOCK, U. S. N. (LATE ENGINEER-IN-CHIEF, U. S. N.)

MR. PRESIDENT: I regret that you have called upon me for a speech. I much prefer not to mar the pleasures of this occasion by attempting something in which I may not succeed, as I have no talent in that direction. I can, however, with much pleasure, say that I subscribe fully to the facts and conclusions as stated by our distinguished friend, Dr. Thurston, as to the great work accomplished by Commodore B. F. Isherwood in the line of scientific investigation and the invaluable service he has rendered to the engineering profession, and I assure you that it affords me much pleasure to be present on this occasion and assist in doing honor to the distinguished guest of the evening.

MR. CHARLES H. HASWELL, FIRST ENGINEER-IN-CHIEF OF THE U. S. NAVY.

MR. CHAIRMAN AND GENTLEMEN: Recognizing and appreciating the compliment of calling upon me, I regret that I do not possess the inherent gift of verbally expressing myself in the manner and extent that I would like upon this very fitting and agreeable occasion. We are met here to evidence our appreciation of the propriety of paying a just tribute to one who so eminently deserves it, but after the full and eloquent address to which we have listened from Dr. Thurston there is little left for

me but to express my full concurrence in all he has said; but there is a tribute of my own which I gladly take the opportunity to submit.

Mr. Isherwood, by his zealous application and untiring researches, aided by mental capacity of a high order, has earned a national reputation that reflects honor, not only on the corps of which he is the senior member, but on the profession of steam engineering at home and abroad.

Now, although we have perpetuated him in brass, yet of his works he may say *exegi monumentum aere perennis;* to which I add, a bust may be destroyed, but recorded history is enduring.

CHIEF ENGINEER D. B. MACOMB, U. S. NAVY.

MR. CHAIRMAN, FELLOW ENGINEERS AND FRIENDS: I arise with considerable trepidation after the remarks of our eloquent friend Doctor Thurston and the guest of the evening, men of fame, not only in this land of ours, but in lands far "remote across the sea," and any words I may say will seem tame in comparison; but, sir, I can not let this happy occasion pass without adding a few words of congratulation to us all for having the pleasure of meeting our old friends—friends of my early manhood, friends of my middle age, and friends of to-day. When I look around and see them flushed, as it were, with the vigor of health, I am reminded of the last words of the great statesman, Daniel Webster, that "we still live," and my heart wells up in thankfulness to our Heavenly Father for His manifold blessings and mercies. Particularly am I reminded of my earlier days of service when I see my venerable friend and first preceptor, Mr. Charles H. Haswell, the *first* and oldest engineer in the United States Naval Service, to whom with Commodore Isherwood, the Corps owes much, as they first had to bear the brunt of the battle which we all have had to fight.

My inception of steam engineering was at a very early age, in 1834; as I remember I was aboard of the first *steam* boat in southern waters on the Escambia river, Florida. She was named the *Escambia* and carried the U. S. mails, freight and passengers from Pensacola, Fla., to the small towns situated on

that river. She was one of the old stern-wheelers, of about one hundred tons. My next experience was on the Mississippi river, on one of the larger boats. I was with my father making a passage from Cincinnati to New Orleans and witnessed a steamboat race, such as was common on our large rivers of the west and south, and when one of the firemen hung wrenches on or sat on the safety valve lever "to keep her from blowing off." I remember it from a circumstance which happened at the time. An old woman had as part of the cargo several casks of hams, and our boat was being beaten. The old woman was intensely interested in the race, and asked the mate "if something could not be done to win it;" to which he replied, "Yes madame, if you'll let me pitch into the fires some of your hams, we'll win the race." To this she consented, and sure enough we drew ahead of the other boat shortly; but after awhile the other boat fired up again and we began to drop astern. The old woman again became very much excited and called out to the mate, "Put in a few more hams, Mr. Mate, a few more hams." The mate knocked out the head of another cask and fired up with the hams, and we beat the other boat before she made the next landing.

In comparing the pressures of steam used now with those which were used forty-five years ago in condensing engines: I was in Boston in 1851, and went on board of a small side-wheel steamer which had arrived from Canada. In looking around I did not see any signs of a steam gauge, and asked the old Scotch engineer where was his steam gauge? He said, "Why there, man, don't you see?" and upon examination I discovered a *small* syphon murcurial gauge indicating *only four and a half inches* as the *extreme pressure*. This was the only steam gauge he had attached to the boilers or engine. The boilers were mere wrought, iron tanks with corners rounded, having man holes, furnaces and ash pits, and *a few* horizontal and vertical braces in them. The engines were of the old side-lever type, similar to and about the same size as the *one* we had in the old surveying steamer Bibb, only there were *two* of nearly the same size (50 inches × 55 stroke) as we had in the *Bibb*. We carried 15 pounds of steam

on a proper gauge. I have often wondered at what the old Scotch engineer would have said and thought of the steam pressure carried on our modern ships.

The bronze bust of our guest is a beautiful piece of workmanship, and a most perfect likeness. May he live many years and his fame increase and be as enduring as the bronze.

PROF. DAVID M. GREENE, C. E. (LATE OF ENGINEER CORPS, U. S. NAVY).

MR. CHAIRMAN AND GENTLEMEN: While I dare not trust myself to undertake an expression of my feelings on this most interesting occasion, I cannot do less than give my hearty indorsement to all that has been so well said by Doctor Thurston and the other gentlemen who have preceded me.

It is not strange that Commodore Isherwood's brother officers, who have enjoyed the rare privilege of being associated with and of serving under him in the naval service, and who admire and love him, should desire to preserve his features in enduring bronze. It gives me special pleasure that, while our friend still lives, we have, through co-operation with our brother Baird, been able to show him the high regard in which he is held by those who were permitted to be his instruments in the accomplishment of his great work for the advancement of the profession of marine engineering throughout the world. It is indeed pleasant to know from our friend's own lips that the evening of his life of patient toil will be cheered and made happier by the recollection of this event and by the assurance which it affords him that both he and his works are recognized and appreciated—*and valued*—as highly as he could wish them to be.

If I may be permitted to refer to my personal relations with Commodore Isherwood, I desire to make this public acknowledgment of my indebtedness to him for all of those hints, suggestions, criticisms and facts, which have been of the greatest practical value to me during my professional career since leaving the service, twenty-nine years ago.

For three years it was my privilege to be one of our friend's trusted assistants in the Bureau of Steam Engineering, in the Navy Department, at Washington. During that period I met

the Chief daily. His assistants were always made to feel rather as associates, engaged in advancing a common cause, than as subordinates, receiving and executing orders from their superior officer. Thus there came to be zealous co-operation rather than perfunctory service.

Nature, whose operations in the domain of steam engineering had hitherto been largely unknown and unsuspected, was persistently and systematically questioned and forced to disclose many of her valuable secrets. Her answers were recorded by the assistants, interpreted by the Chief, and subsequently given to the world for the benefit of mankind, in those incomparable works which are known and recognized as authorities wherever the English language is spoken or understood.

Our Chief was unsparing in criticism, generous in approval and commendation, and always the same genial, kindly gentleman.

Need I, then, offer an apology for pronouncing in this presence the verdict—which I am sure will be sustained by posterity—that Commodore Isherwood is the greatest living marine engineer, and, more than that, that he is a profound philosopher?

What more need be said of any man?

DR. CHARLES E. EMERY (LATE OF ENGINEER CORPS, U. S. NAVY).

MR. PRESIDENT AND GENTLEMEN: With others I heartily subscribe to the tribute of respect and add the testimony of personal knowledge to that of the orator of the evening, relative to the great value of the early scientific work of our most distinguished guest in advancing steam engineering from an art to a science. I wish, however, to call attention to the fact that, while thus engaged in the scientific investigation of the steam engine, he never lost sight of those practical essentials necessary to secure successful mechanical operation. Under his direction a steam navy was built in the greatest haste. It was necessary that the machinery should operate reliably and continuously without the possibilities of a breakdown in the presence of the enemy. Most of us know that this was accomplished in the most perfect manner. Our Chief, notwithstanding his fondness for calculations of the most

minute character, realized that the machinery must be built in great haste, and necessarily in some shops with inferior facilities, and decided to use moving parts with dimensions apparently unwarranted by our knowledge of the strength of materials; but the results warranted this step, as breakdowns were of very rare occurrence. The cap of the crank-pin journal of the engine assigned to my care on the *Nipsic* was cracked from front to rear for three-fourths of its width, only holding by about three-fourths of an inch of solid metal on each side; but, when I discovered and proved it to disbelievers, the vessel was so much required and the temporary shop at Port Royal so much occupied, that the board called to examine it decided that the metal remaining was sufficient to resist the strains, and by calculation this was so, and no breakage ever occurred. There must have been all sorts of hidden defects in the hastily made forgings on all the ships built during the war, and the use of an enormous factor of safety was the only way to prevent breakdowns. The lesson is that the habit of close investigation along scientific lines did not prevent our Chief from the exercise of the best of judgment as to mechanical details.

I wish also to testify to a trait of character of our War Chief of Bureau which has not yet been brought out by others, to wit: his kindness to subordinates and anxiety in regard to their future growth in the higher elements of their chosen profession. I say with deep gratitude that whatever reputation I may have achieved as an engineer is in a very large measure due to Mr. Isherwood. Naturally of an investigating nature, I wished to bring myself to his attention when a simple assistant engineer, and, as a means of doing so, wrote calling his attention to a drawing I had submitted at my examination for promotion. The reply will be better appreciated by stating that the drawing was nothing to be ashamed of, very well executed and showed an excellent knowledge of the principles of kinematics, inasmuch as it illustrated an instantaneously adjustable Stevens cut-off embodying comparatively simple means for dropping the toes and correspondingly increasing the lead as the cut-off was shortened. Mr. Isherwood responded somewhat to the effect that, while it was praiseworthy

to do anything well, it was his earnest advice that I apply myself to the study of principles rather than of mechanism. This, without attempting to use his exact language, evidently was the keynote of Mr. Isherwood's success. By continued study and investigation of the principles which fixed the governing proportions of steam engines and boilers, he developed factors which have enabled the profession since to make designs with absolute knowledge of what the results would be for the conditions assumed.

I may add further that it appears probable that investigations, of the character early made by Mr. Isherwood, may reveal results in relation to our modern steam engineering somewhat similar to those he early established. He showed that, under the conditions obtaining in the engines he tested, it was most economical to limit the expansion of steam, and consequently the size of engines, more than had previously been the custom. We can now see that the proportions adapted for low pressures were not the most economical for higher pressures, but it is a grave question if any actual loss during average working resulted from this. We had in our practice for the first time boilers which would supply all the steam the engines could work off, consequently the maximum speed could be obtained at any time and continued indefinitely. This was something new for a steamship. It was something to be sought for and not readily found, even in the present. Undoubtedly the economy was not the maximum, when the machinery was forced to its utmost, but this occurred very rarely, probably not one per cent. of the time, whereas the engines were of proper size to secure the maximum economy possible during the long periods requiring moderate power, so the average results were as good and generally better than would have been obtained with any other adaptation of simple machinery using the steam pressure available.

It is evident to me that the same principle can be applied in the proportions of our modern compound engines. Some have realized it, and it is not uncommon on the more noted of the transatlantic steamers to hear the safety valves blow for a short interval after changing watches and cleaning several fires, show-

ing the close adaptation of the engines and boilers. On the contrary, I was on a yacht recently, designed to run with 200 pounds of steam, which had engines so large that when linked up and running at full boiler power it was necessary to keep the throttles nearly closed. The advantage of keeping the engines rather small for the work and the boiler power ample, as in Mr. Isherwood's practice referred to, will be evident to all, on account of the very superior economy obtained in running during the greater part of the time at reduced power.

Further than this, I believe that the limit of desirable steam pressure has been reached, and that possible economy in a scientific rather than a theoretical sense would be attained by not attempting the higher pressures now found practicable. I recently had occasion to investigate a number of compound engine plants operating factories in the East. The one that was most vaunted and claimed to be securing a horse power for 1.3 pounds of coal, required $2\frac{1}{3}$ pounds. Several others required over 2 pounds, and in only one case did the cost fall as low as $1\frac{3}{4}$ pounds, and this was one of the earlier engines designed as the immediate results of the analysis I published of experiments with compound and non-compound engines, made, under the direction of Mr. Loring and myself, with engines of different kinds on Revenue cutters, which I designed so as to make such a test practicable twenty-four years ago, and before the revival of the compound engine here and its application to vessels of the U. S. Navy. The proportions of the cylinders of the factory engine referred to were more nearly like those I had used for lower pressures and set forth in my analysis, and the water consumption for this long-stroke engine, small clearances and a steam pressure of 125 pounds was 16 pounds, the chief economy being in the boilers, whereas the compound engine of the series I designed so long ago gave a horse power for 18.4 pounds of water per H.P. per hour with only 70 pounds steam pressure. It is certain that these modern engines with high steam pressures will, under experimental conditions, do 25 to 33 per cent. better than the figures stated, but it is equally certain that they *do not do it* under the conditions of ordinary practice. The same gene-

ral results are shown on shipboard, notwithstanding there is the same talk about getting a horse power for 1.3 pounds. The fact is that few steamers use less than 2 pounds per H.P. and the average is higher than that. In some cases, with particular provisions for securing economy from the boilers, better results have been obtained, but it is a question whether any special mechanism is proper for use on a naval vessel liable to the exigencies of war.

Since the average cost of a horse power is already considerably above 2 pounds, and as this is as true for engines carrying 200 pounds of steam as for those carrying 125 pounds, the general result, independent of particular cases, is that it is not desirable to carry the higher pressures, with their attendant increase of radiation, liability to external leakage, and particularly the liability to large wastes by inconsiderable leaks in the cylinders and valves and the increased wear and friction of high-pressure packings. If this general proposition be true, another incidental advantage follows, to which I have already called attention in the JOURNAL, viz: the possibility of abandoning the intermediate cylinder of a triple-compound engine and the restoration of the 2 or 3-cylinder compound engines, properly proportioned to do the work economically. The triple-compound engines are particularly unfitted for variable powers. This is recognized in the Eastern mills, and compound engines are used exclusively to assist water-wheels even for pressures up to 180 pounds. The compound engine with pressures exceeding 150 pounds would not be desirable on shipboard, as proper results could not be secured with a a simple valve gear, but with lower pressures there would be no trouble whatever in using such engines even with simple lap-valve cut-offs, and the worst penalty to secure best economy would be an independent cut-off for the small cylinder, as in my design of twenty-four years ago. These suggestions are not criticisms of the policy of anyone. We desire to compliment the present management of the Bureau and express our love for its Chief, but only by suggestion, discussion and investigation can the truth be known. The suggestions are made here because

they are in the line of Mr. Isherwood's earlier work, and a correct principle lives through all time.

I have, however, thus far neglected to state that, although the high steam pressures do not give increased economy in practice, they have enabled the mean pressure, referred to the large cylinder, to be increased from 25 up to 40 pounds, and in small engines up to 50 pounds, which with higher speeds, better material and closer design has so greatly decreased the size and weight of steam machinery. This has been partially defeated in many cases by attempting with higher pressures greatly increased expansion, which, though economical on a test, is a blunder for variable power and long continued use where minor repairs cannot be promptly made. We must recognize that, in the suggested decrease of pressure, which can certainly be obtained without decreasing the economy in actual practice, we must not increase the size of engines so that, even without the intermediate cylinder, they will be heavier than those for which they are substituted. Just where the limit is cannot be determined in a hasty discussion of this character. I only wish to call attention to the fact that apparently such a limit exists and that the efforts of thinking engineers can well be directed to its exact definition under particular conditions.

MR. CLARK FISHER (LATE OF ENGINEER CORPS, U. S. NAVY).

GENTLEMEN: Any additional eulogy of our distinguished Chief Isherwood from me is superfluous. His eminence in all things pertaining to naval engineering is and has long been recognized throughout the scientific world; his untiring industry, original investigations and executive ability during eight years as the first Chief of the Bureau of Steam Engineering are well known to all of us. It was through all the hurry and tumult of the war, when the energies of any ordinary man would have been overtaxed, in the creation of an entire Navy, in the building of new ships, repairing and remodeling the engines of purchased vessels and directing affairs in the several navy yards. At any time he could tell you the exact condition of each of the more than six hundred vessels in the different squadrons, with all the de-

tails of engines, boilers and screw propellers. Yet, in the midst of all this, he was carrying on simultaneously dozens of carefully arranged experiments, tabulating results and writing books about them. Nothing escaped his scrutiny. Ferry boats, captured blockade runners or tugboats, with anything novel in those essentials, were subjected to his investigations and the results recorded. Among these I had the good luck, as First Assistant Engineer, to be assigned to the charge, in New York Navy Yard, of an extensive and exhaustive series of experiments on boilers and fuels under his immediate direction, intended to be completed in six months, but so extended and enlarged that they were continued for nearly three years.

Naturally, I got to know him intimately in the course of those experiments. His alert, logical mind and immense fund of knowledge on all subjects, professional, literary and social, won my admiration, and I loved that man, who, with kindly smile and helping hand, always remembered those under him, whether officer or man. He had that faculty characteristic of real greatness—he could make more men follow him, work harder for him, and feel personal interest in such work, than any officer I have ever known. Besides making men work with a will and love of it, he instilled a wholesome dread of any carelessness or error, for our Commodore was not only quick to discover a mistake, but he was never at a loss for incisive words expressive of his opinion of the culprit and his work, or lack of it. Naturally, those of us who succeeded in obtaining his approval became more and more attached to him. In thoroughness, exactness and ingenuity as an experimenter no man has ever excelled Mr. Isherwood. His strongest, persistent instructions to me were: "Whatever your investigations, leave nothing omitted nor imperfectly done. In establishing conclusions, make your experiments so exact that if under the same conditions they should be repeated by some other experimenter a hundred years hence the same results would be confirmed." A frequent expression of his was, "It is Truth we are after, nothing more and nothing less." An experimenter has no business to have an opinion except after exact experiment has proven it.

As a sequel to over 180 experiments with coal—anthracite and bituminous—and coke, none of them of less than forty-eight consecutive hours, most of them eighty hours and many of one hundred and twenty hours, the only conclusive and exhaustive experiments ever made on petroleum as fuel for steaming purposes in this country or in any other were made by myself then.

After unsuccessful attempts with many different projects of outside inventors, the explosion of one sending me to the hospital for a month, I finally devised the first successful system of the atomizer by steam or compressed air projecting, inclosed within it and as a vapor, that liquid into the furnace now universally adopted wherever petroleum is used as a fuel. One ton of crude petroleum will evaporate as much water as $1\frac{2}{3}$ tons of coal and *no more.*

As I look upon the bust in bronze before us my heart swells with emotion. We do not need it to remember him, but future engineers will know from it what were the features, the expression and the head of the man who has done such brilliant and lasting work for his country and for the profession of mechanical engineering.

MR. E. E. ROBERTS (LATE ENGINEER CORPS, U. S. NAVY).

MR. CHAIRMAN AND GENTLEMEN: I feel much honored by the invitation of our Chairman to make a few remarks at this time, and I am also much flattered by the kind words which he has said in regard to the Roberts Boiler. This is no time at which to advertise the latter—and I will, therefore, merely say that the record of this "successful monstrosity" speaks for itself.

Like the rest of you, I received a printed invitation from Mr. Baird to attend this function, but felt obliged to send regrets, as I foresaw that pressure of business would prevent my attendance. Mr. Baird would not take "no" for an answer, and sent me a second urgent invitation to attend. He offered several inducements. One was the fact that I would have an opportunity to taste "terrapin" as cooked in Philadelphia. Another was the excellence of the champagne, but what really brought me here was the fact

that he stated that I would hear an elaborate eulogy of Commodore Isherwood by Dr. Thurston. Dr. Thurston's address has fully repaid me for the trip. I had supposed that the terrapin would be excellent, because I was under the impression that it had to be cooked slowly, and that, therefore, Philadelphia would excel in this particular. I had my doubts, however, whether the champagne corks would be drawn with sufficient rapidity in this city. My mind is now at rest on this subject, and I hope you will not misunderstand me when I state that I feel almost "too full for utterance."

Mr. Baird has a habit of illustrating his communications with very excellent free-hand drawings, and he delineated, on his second communication, a figure of an alleged orator, which I took personally.

I do not claim to be a handsome man, but I hardly think that the caricature does justice to the subject, except, possibly, in regard to the rotundity of his person and the baldness of his head; but, joking aside, I will say that I am very glad to be here with you to-night.

It was my good fortune to enter the Regular Service of the Navy in 1861 as a Third Assistant Engineer. I afterwards held the rank of Second Assistant through promotion, but, notwithstanding this promotion, I still stood in great awe of the, even then, celebrated Engineer-in-Chief of the Navy—our present guest. Since those days he has added largely to his even then world-wide reputation as a scientist.

When I was very young, I was under the impression that the facts related in the New Testament referred to some locality entirely foreign to this mundane sphere. I was surprised in after years to discover that they actually occurred on this earth of ours. My feelings towards the great Engineer-in-Chief of the United States Navy, at that time, partook of this same feeling. He was too far above me for me to fully comprehend him. I doubt whether any of us are fully able to comprehend him yet. He seemed in those days to resemble Mahomet's coffin, and to be located somewhere between heaven and earth.

During the last thirty-five years, I have learned much from

the writings of Commodore Isherwood. There have been attempts to controvert some of his opinions, but I have never yet known him to make a mistake. He always comes out on top.

I am proud of the fact that I have been permitted to be one of the subscribers to this most excellent bust of the Commodore. I really do not think that the office of the Engineer-in-Chief of the Navy Department is the right location for it. All *engineers* are acquainted with him and with what he has done. What I desire, personally, is that this bust should be placed where others than engineers can see those intelligent features and, when inquiring as to the original, can be informed in regard to the great life work of Commodore Isherwood. I am glad to see the bust in full uniform. Notwithstanding the fact that we are all in evening dress to-night, I believe there is a hazy impression in some minds, that we are simply a set of mechanics who absorb our knowledge through our soiled fingers.

If this bust is placed in the proper location, where it can be seen by the general public, I think it will have a tendency to inform those of the public who need it, that we, as well as other naval officers, have an *esprit de corps* of our own, and consider ourselves "officers and gentlemen."

But, gentlemen (looking at his watch), I am reminded of the fact that our Chairman asked me to make a few brief remarks, accompanied by the statement that it is nearing midnight, that to-morrow will be Sunday, and that we are in Philadelphia. I will, therefore, not tax your patience further.

MR. N. P. TOWNE (LATE CHIEF ENGINEER, U. S. NAVY).

I did not expect to be called upon to speak to-night, and I have already filed several petitions with the President that I should be omitted from his list. I had reason to think that my request was granted, but another example of the injunction, given several years ago, not to put our trust in Princes, is before us, and as a consequence I am delegated to add my feeble chirp to the songs of the birds which we have heard with so much pleasure.

I would like to call the attention of the Chairman to one

fact that probably escaped his notice, though all of us, who were under Mr. Isherwood's command when he was at the head of the Engineer Corps, have had it impressed upon them. This fact is simply that the guest whom we are assembled to honor to-night never used the power which he wielded to make anyone uncomfortable unless it was for the good of the country. Mark, then, the difference: this man, clothed with a little brief authority, instantly grasps the opportunity to make miserable those whom he imagines rightly—— (Laughter.)

Mr. President, I shall not lay myself liable by my *expressions* to the penalties which may be inflicted for contempt of court, no matter what I may *think*.

I have noted that Doctor Thurston, in his remarks, calls our attention to the difference in the opinions held now and formerly, as to the status of the engineer.

Gradually, as he has become known, the position of the engineer has risen, until now his education and scientific acquirements are conceded to be, as Doctor Thurston says, fully equal to those of the formerly so-called learned professions.

I would call attention to the fact that now, in addition to mechanical, mining, electrical, sanitary, civil and many other engineering specialties, we know of legal engineering as a profession, and I have heard the name of surgical engineers applied to those eminent men who seem to unite the profession of the engineer to their own in their wonderful operations in straightening the deformities of nature and remedying her diseases, and, still further, I hope that shortly before the millenium we shall see theological engineers, and absorb into one common brotherhood all the now learned professions as different branches of the great engineering tree.

Limit of time, limit of endurance on your part and limited ideas on mine, prevent my continuing this oration, but I will add to what has been said before in honor of our distinguished guest, that as the history of Cæsar and Napoleon is to the military history of nations, so is that of James Watt and B. F. Isherwood to the history of scientific engineering. Struggling against malice, ridicule and envy, he pushed his way by unequaled

labor and brilliant conceptions, until to-day he stands with his active labors finished, in hale and hearty age, as the honored founder of modern engineering science.

MR. J. J. DE KINDER, M. E.

MR. CHAIRMAN, GUEST OF THE EVENING AND GENTLEMEN: Although not an engineer, or even an ex-engineer, of the United States Navy, I feel that I am justified in saying that, as much as any one here to-night, I bring homage to Mr. Isherwood. Long before I had an idea of becoming a citizen of this great country I owned a copy of the works of Mr. Isherwood. I think it is safe to say that every engineer, no matter how ambitious he may be to investigate the entire field of engineering, has yet some particular hobby, if I may call it by that name, some specialty, which appeals to him more than any other. I confess that the study of Isherwood's works very largely led me into what I consider my hobby in engineering, namely, the experimenting with different kinds of fuels under different conditions and under different types of boilers, and believe few have devoted more time, thought and labor in this direction. Mr. Isherwood's works and Haswell's, also, early awoke in me a desire to become better acquainted with the men who have made and are making the name and reputation of the Engineer Corps of the U. S. Navy famous the world over. And just here, in view of the events which are stirring around us, permit me to say that, as I served the red, white and blue in my old home [Holland], that little country no larger than the state of Maryland, which dared to wage and did wage war successfully for eighty consecutive years against Spain, when that country had reached the zenith of its power, so when the call shall be made to uphold the honor of the red, white and blue of my new home, our common country, I shall be with you. (Applause.)

MR. JARVIS B. EDSON (LATE OF ENGINEER CORPS, U. S. NAVY).

MR. CHAIRMAN AND GENTLEMEN: I fully appreciate the opportunity you afford me to add what I may be able, in testimony of the love and esteem we feel toward our distinguished guest, but can I do better than endorse what has been so ably and compre-

hensively stated by those before me? I think not, and therefore will rest by reminding you of our indebtedness to the Chairman, Mr. Baird, for his efforts in our behalf in having conceived and made possible the pleasure we enjoy in effectuating this, our testimonial to Mr. Isherwood; and I therefore presume upon his very modest and unostentatious nature, by proposing a vote of thanks to him, to which all will signify by saying aye. The vote is unanimous.

MR. THAD. S. VANDERSLICE (LATE OF ENGINEER CORPS, U. S. NAVY).

GENTLEMEN: It is a privilege to be an engineer, but a distinction to have served with the brainy men of the Engineer Corps of the Navy of this Republic. During the war of the rebellion, I had that distinction, which continued for eight long years, and that association afforded me an experience which has been of much value to me in the practice of law, which I have followed since resigning from the Service. My heart wanders back to the days of my youth, and the recollection is as the music of a summer dream. The guest of the evening was always so far above us in intellect, genius and industry that we looked up to him. It was not long before I discovered that eminent engineers on the other side of the Atlantic, who had combatted him, were also looking up to him as an international authority. This early engineering education in mechanics, physics, hydraulics and chemistry has stood me in good service in my legal practice, and has enabled me to win professional victories that would otherwise have been quite impossible. The distinguished guest of the evening has what lawyers call "statement." He was always able to so state a case as to make it very clear to his hearers. I am indebted to him for good example in that.

COL. LEVI R. GREENE (LATE OF ENGINEER CORPS, U. S. NAVY).

MR. CHAIRMAN: It lacks but a few minutes of Palm Sunday, before the advent of which we surely must adjourn, and before doing so I desire to make a motion which I am confident will be assented to unanimously.

Before making the motion, however, I desire to express my gratification at here meeting at this time the guest of the evening,

to whom I owe whatever success in life I have had as an investigator and an experimenter in our profession. It was due to his kindness, during my experience in the experiments made in pulverized fuel and metallurgy, and in super-heating steam, that I obtained the knowledge that has been of the greatest benefit to me in my course of engineering.

I also desire to express my gratitude to our venerable friend, Mr. Chas. H. Haswell, who all my life has been my constant friend.

The motion, gentlemen, which I desire to make is a vote of thanks to the orator of the evening, Doctor Thurston, for the eloquent address to the guest of the evening. I know of no one better qualified to have made it, and I desire personally to thank him and to say that it is what might have been expected from the son of his father, whom I had the pleasure of knowing well as a skilled mechanician.

The vote of thanks was carried with applause.

LIST OF SUBSCRIBERS TO THE ISHERWOOD MEMORIAL OTHER THAN NAVAL OFFICERS.

Prof. W. S. Aldrich, Jas. T. Boyd, Miers Coryell, W. B. Cowles, Prof. M. E. Cooley, J. B. Edson, F. B. Dowst, Dr. C. E. Emery, R. H. Fitch, Clark Fisher, Levi R. Greene, Prof. D. M. Greene, Jos. S. Greene, J. T. Hawkins, J. B. Houston, G. R. Holt, Chas. H. Haswell, P. O. Keilholtz, E. D. Leavitt, A. M. Mattice, J. F. McCutcheon, Leo Morgan, H. C. McIlvane, Wm. Roberts, E. E. Roberts, Fred. Schœber, Sidney L. Smith, N. P. Towne, Dr. R. H. Thurston, John D. Van Buren, George Westinghouse, Jay M. Whitham, J. R. Allen, W. H. Bailey, M. T. Davidson, B. F. Sturtevant Co., Andrew Fletcher, Wm. Fletcher, Stevenson Taylor, T. J. Faig, N. G. Herreshoff, Warren Hill, Jas. A. Howatt, L. Katzenstein, T. F. Rowland, Nathaniel McKay and G. C. Sims.

It was decided by the subscribers that the most appropriate place for the permanent location of the bust of Mr. Isherwood would be the Congressional Library at Washington, and a committee was empowered to arrange with the proper authorities for such location.

NICKEL STEEL FOR CRANK PINS AND AXLES.

By H. F. J. Porter, M. E.

[Reprinted from "American Machinist."]

If an engineer wants material to sustain severe usage in the nature of alternating stresses he should select a material possessing a very high elastic limit. It is not unusual to find engineers who prefer to use wrought iron for their locomotive crank and crosshead pins and axles in preference to steel, because, as they say, "steel, being crystalline, is brittle and snaps off suddenly under such service, while iron, having fiber, is tougher and yields before breaking."

There is not one of them who would advocate the use of the old "cut nail," which was made of iron, in place of the "wire nail," which is made of steel. The fiber in wrought iron is due entirely to the slag, which could not be eliminated from it in the process of its manufacture.

All metals, iron and steel among them, are initially crystalline. We hear of many forgings having failed in the past from a mysterious so-called "crystallization from shock" or "vibration" in service. We all ought to know that metals crystallize only in cooling from a fluid to a solid state, and that any unusual crystallization shown in a fractured forging was there when the forging was made and was due to improper heat treatment during manufacture.

There is no longer any mystery about the breaking of steel. If the coefficient of elasticity of the metal exceeds by a large factor of safety the external stress applied, the life of the material will be long. In other words, the stronger the material the longer it will last under any given service. The cause of the final failure to longer endure the stresses applied is the gradual overcoming

of the internal molecular force of cohesion. This gradual weakening of the metal has been given the name "fatigue." Iron and steel are more amenable to the known laws of the universe than we had previously given them credit for being; the same laws of nature under which "continuous droppings will wear away a stone" are applicable to these metals.

The rupture of a bar of wrought iron by *tension* is caused in any of the following ways:

By 1 application of 55,000 pounds per square inch.
By 800 applications of 51,500 pounds per square inch.
By 107,000 applications of 47,000 pounds per square inch.
By 341,000 applications of 42,500 pounds per square inch.
By 481,000 applications of 38,000 pounds per square inch.

A piece of spring steel, subjected to *bending*, broke as follows:

Under 81,000 applications of 95,000 pounds per square inch.
Under 154,000 applications of 85,000 pounds per square inch.
Under 210,000 applications of 75,000 pounds per square inch.
Under 472,000 applications of 65,000 pounds per square inch.
Under 539,000 applications of 58,000 pounds per square inch.
Under 1,165,000 applications of 53,000 pounds per square inch.

Speaking generally regarding iron and steel for any given stress, a certain number of repetitions produce failure; the greater the intensity of stress the smaller the number of repetitions. We know also that the stress required to cause failure is less, and, roughly speaking, only one-half as great when the metal is strained alternately in opposite directions, as in crank-pins, axles, etc., as where it is strained in one direction only, as in eye-bars of bridges. The more the metal is maltreated the shorter the time it will endure. If we can make the "range" of stress low enough a practically unlimited number of repetitions is required to cause failure.

Numerous tests have been made by revolving long bars supported at both ends and with a weight in the middle, thus imitating those conditions which occur in actual practice in such machine parts as railway axles, engine shafts, crank-pins, etc., where the fibers of the metal are subjected to stresses, continually varying from tension to compression. It has been found from these tests that within a certain limit, which is approximately one-half

of the ultimate strength, the metal is elastic, and that if strained beyond this point its working strength is exceeded and it can no longer be depended upon to sustain even minor loads. The fact that a metal possesses a certain elastic limit, elongation and contraction of area, when ruptured by once loading, fails to convey an adequate idea of what the same metal will do under circumstances of repeated stresses, or when these stresses are applied in alternate directions, as they are in practice. These "endurance tests," therefore, have been made in connection with the usual standard tests above mentioned in order to determine the relations that exist between the two.

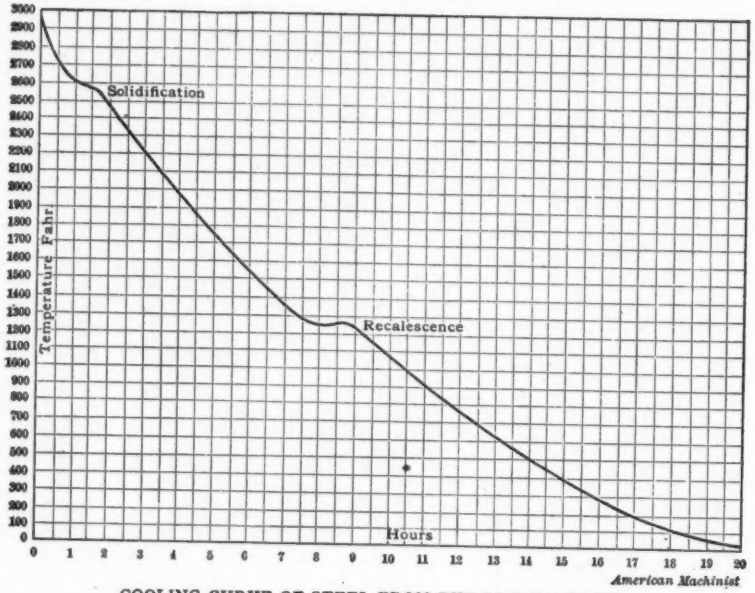
Following are the results of tests on bars broken from time to time during the past few years at the Watertown Arsenal. The records of the wrought-iron bars are the average of a large number of tests:

Fiber stress, pounds per square inch.	40,000	35,000	30,000
	Revolutions.	*Revolutions.*	*Revolutions.*
Wrought iron breaks after	59,000	175,000	625,000
.15 per cent. carbon steel breaks after	170,000	765,000	.....
.25 per cent. carbon steel breaks after	229,000	.....	.....
.35 per cent. carbon steel breaks after	317,000	5,100,000	.....
.45 per cent. carbon steel breaks after	976,000	.....	.....
.55 per cent. carbon steel breaks after	.....	9,600,000	.....
.65 per cent. carbon steel breaks after	3,689,000	.....	.....
.75 per cent. carbon steel breaks after	.....	15,000,000	12,550,000
.85 per cent. carbon steel breaks after	.....	19,000,000	16,300,000
.95 per cent. carbon steel breaks after	.....	.....	.....
1.05 per cent. carbon steel breaks after	.....	.....	*50,000,000
3½ per cent. nickel steel, carbon .25 per cent. to .30 per cent.	1,850,000	.....	.....
4½ per cent. nickel steel, carbon .25 per cent. to .30 per cent.	2,360,000	.....	.....
5½ per cent. nickel steel, carbon .25 per cent. to .30 per cent.	4,370,000	.....	.....

* Not ruptured.

These results, which are representative of many, show that the material, after a certain number of repetitions of stress within the elastic limit, breaks with fewer subsequent repetitions.

It would naturally appear likely that any gradually progressive alteration or "fatigue" of the bar would be manifested in



COOLING CURVE OF STEEL FROM THE LIQUID STATE.

some way in alteration of the ultimate strength, elastic limit or elongation of the metal when tested in the ordinary way. This, however, does not appear to be the case. A bar subjected to so many repetitions of loading that it is known to be on the point of breaking, or a piece of bar already broken in an "endurance" test, gives in the ordinary testing machine no indications that its strength or ductility has been altered. Careful consideration of the results of endurance tests so far made leads to the recommendation of material for forgings, if they are to be subjected to frequently alternating stresses, which shall have a very high elastic limit, and that they shall be so proportioned that these stresses shall at all times lie far within this limit. Steel, not wrought iron, should be the metal used, and the higher the carbon content of the metal the higher will be the limit and the longer will be the life of the piece. A low percentage of nickel in its composition will increase its life still further.

Referring to the diagram, if we note the rate of cooling of a steel ingot from the point of solidification to coldness we shall see that the temperature will fall regularly nearly the same amount in equal divisions of time, until, between 1,300 degrees and 1,200 degrees Fahrenheit, a point (depending on the carbon content) is reached where the temperature suddenly stops falling, and either remains stationary or perhaps rises for a short time, and then the rate of cooling continues regularly. This point, where the change of rate takes place, is called the "recalescent" point, and from chemical and physical tests we know that a change in the structure of the steel occurs here.

The fluid steel begins to crystallize at the point of solidification, and the slower the rate of cooling from there down the larger the crystals will be when the ingot is cold. At the point of "recalescence," however, it would seem as if the crystallization, so to say, *locks itself*, for after the ingot has become cold, if we reheat it to a temperature *below* this point, on again becoming cold we shall find that the crystallization is not affected, but if we reheat it a little *above* the recalescent point, when it is again cold the crystallization will be found to be much smaller than before.

In the foregoing process, beginning with the cold ingot (which

we will assume has cooled slowly and is therefore composed of large crystals), we first reheat it up to a forging temperature of from 1,800° to 2,000° Fahrenheit, thus destroying all crystallization, and producing an amorphous condition. As we put it under the forging press it begins to cool, crystallization at once setting in. The work of forging tends to check crystallization, just as the disturbing of water which is below freezing point will delay the formation of ice crystals. The work of forging may or may not continue until the temperature has fallen below the recalescent point, but more or less crystallization has occurred, and has been disturbed and distorted. The work of forging has, moreover, proceeded from one end of the piece to the other, so that the two ends may be entirely different as far as their internal condition is concerned. The forging is now full of pulls and strains about which we know nothing. The extent of the strains is made evident when a forging, finished as above described, has a cut taken from it in a lathe or has a key-way cut on one side. The strains in the fibers which are cut are relieved and the piece invariably springs out of "true."

To relieve these strains the forging should be carefully and slowly heated to a temperature slightly above the recalescent point, and then allowed to cool slowly. If the forging, on being heated slightly above the recalescent point, is suddenly dropped into a bath of cold oil, no time is allowed during the cooling process for crystals to form, and the amorphous condition of its structure at that temperature is retained. This character of heat treatment is called "oil-tempering," and is followed by further heat treatment to relieve the metal of any hardening effect due to the cooling process. Annealing lowers the ultimate strength and elastic limit of steel, but increases its ductility. Oil-tempering not only restores the ultimate strength and elastic limit, but increases the elongation and contraction very considerably. The very best steel suitable for forgings will not last indefinitely under a fiber stress of 40,000 pounds per square inch, and the life of wrought iron and mild steel under even lower stresses is comparatively short.

Crank-pins, axles, etc., are generally made of material which

has initially little strength to resist fatigue. They are loaded up, during the process of forging, by stresses which may closely approach the elastic limit before any stress whatever is put upon them from outside. A severe compression stress, sometimes itself closely approaching the elastic limit, is applied to the metal by the process of forcing them into wheels, and it is not surprising that their life is short at the point where this stress is applied. For such service as is required of crank and crosshead pins, axles, piston and connecting rods and all forgings subject to stresses alternating from tension to compression, a metal possessing the very highest elastic limit possible should be supplied.

We must be sure that our forgings are free from internal strains. We must also so proportion them that these stresses will be well below the elastic limit of the metal if we desire to insure lasting qualities, remembering that range of stress when the stresses are alternating has a double value.

The first practical application of the improvement in the quality of steel by the use of nickel was in the production of open-hearth armor plate. This alloy increased the toughness of steel of a given hardness or tensile strength so as to add greatly to its resistance to cracking from the shock of projectile impact. An examination of the physical characteristics of this metal shows it to possess valuable qualities which explain its toughness and resistance to shock. The nickel, replacing part of the carbon, with a given tensile strength increases the elongation, and to a greater degree the contraction of area, in test pieces at the point of fracture. Its effect upon the elastic limit, however, is of the greatest importance, as it raises this quality in a marked degree relatively to the tensile strength, and thus insures a combination of elastic strength and ductility unknown in any other metal. The presence of the nickel also renders the steel sensitive to the good effects of tempering, and the desirable qualities above mentioned are accentuated by this treatment. Endurance tests show that this metal is eminently adapted to resist fatigue, and experience in actual practice confirms these tests.

Test bars of this metal ½ inch in diameter and 2 inches long between measuring points show the following physical properties:

Tensile strength, 80,000 to 95,000 pounds per square inch.

Elastic limit, 50,000 to 65,000 pounds per square inch.

Elongation, 25 per cent. to 22 per cent.

Contraction, 60 per cent. to 50 per cent.

Many railroads are now taking up the use of this metal generally, having tested it experimentally and found to their satisfaction that by a small initial increased expense they can save largely by having fewer breaks with their attendant delays and damage.

THE YARROW-SCHLICK-TWEEDY SYSTEM OF BALANCING ENGINES.

(Reprinted from "Engineering.")

In accordance with the promise made in our article on the Carron Company's twin-screw steamer *Avon*, we publish this week several illustrations to show the *rationale* and the results attained, not only in this steamer but in others, by the adoption of the system of balancing perfected in collaboration by Mr. Otto Schlick, Mr. A. F. Yarrow and Mr. John Tweedy, of Messrs. Wigham Richardson & Co., and now being extensively adopted by the best known firms. The system may be said to have been evolved out of the quadruple-expansion engine, in the development of which Mr. Tweedy and Mr. Walter Brock, of Messrs. Denny's firm, have been closely associated for a number of years. But while Messrs. Denny adopted in the early days the two-crank tandem type, Messrs. Wigham Richardson & Co. have always fitted the four-crank arrangement, and during the last ten years they have constructed quite a number of such engines, working at pressures varying from 180 pounds to 215 pounds per square inch; fifteen sets have been built by them during the last three years.

A set of the latest engines of the class has cylinders 24 inches, 34 inches, 57 inches and 74 inches in diameter respectively, and the stroke is 54 inches, the working pressure being 210 pounds per square inch. The high-pressure cylinder is placed forward, and the first-intermediate cylinder aft of the second-intermediate and low-pressure cylinders. These two cylinders are bolted firmly together, allowance being made for expansion in the machining of the castings. The outer cylinders, being small in diameter, with very little overhang for the steam chest, are quite separate from the remaining cylinders—they are not attached to them in any way—being supported only by the columns, which are spread

forward and aft to give a stable bearing. In practice it has been found that the cylinders so arranged are perfectly rigid and satisfactory, while disturbance due to expansion is entirely avoided. A plan view of these engines is shown in Fig. 4.

To prevent vertical distortion through change of temperature, and at the same time to avoid the use of a long condenser which, even in three-crank engines of any size, is often found objectionable, the back columns do not form part of the condenser, but are carried right down to the bed plate. A short condenser is placed either immediately below the exhaust orifice of the low-pressure cylinder, as in the present case, or, when sufficient floor space is not available, at the side of the ship, under the deck, in cases.

The front supports consist of four standards bolted together in pairs, these standards being suitably shaped to receive the crosshead guides. The wide arch formed by the lower parts of each pair of standards gives good access to the engines. In the engines described there are four Y columns at the back, tied also at their upper ends; but in subsequent engines built by Messrs. Wigham Richardson & Co., the back columns have been made exactly the same as the front columns. The crank shaft is supported on six bearings fitted into a substantial bed plate in the usual way. The pumps and other details are also arranged much as in the ordinary engines.

Another modification of quadruple-expansion engines designed to occupy less fore and-aft space has been built by Messrs. Wigham Richardson & Co. during the last two or three years, a plan view being shown in Fig. 10. In these engines the steam chests of the low-pressure and second intermediate cylinders are placed at the sides, the valves being worked by rocking levers. The space required for engines of this type is exactly the same as for triple-expansion engines built in the ordinary way. The particular engines illustrated by Fig. 10 have cylinders 22½ inches, 32½ inches, 47½ inches and 69 inches in diameter by 48 inches stroke; working pressure, 215 pounds.

In regard to the economy in fuel of such engines, we are able to state, after the perusal of private documents prepared by the owners of certain ships fitted with Messrs. Wigham Richardson

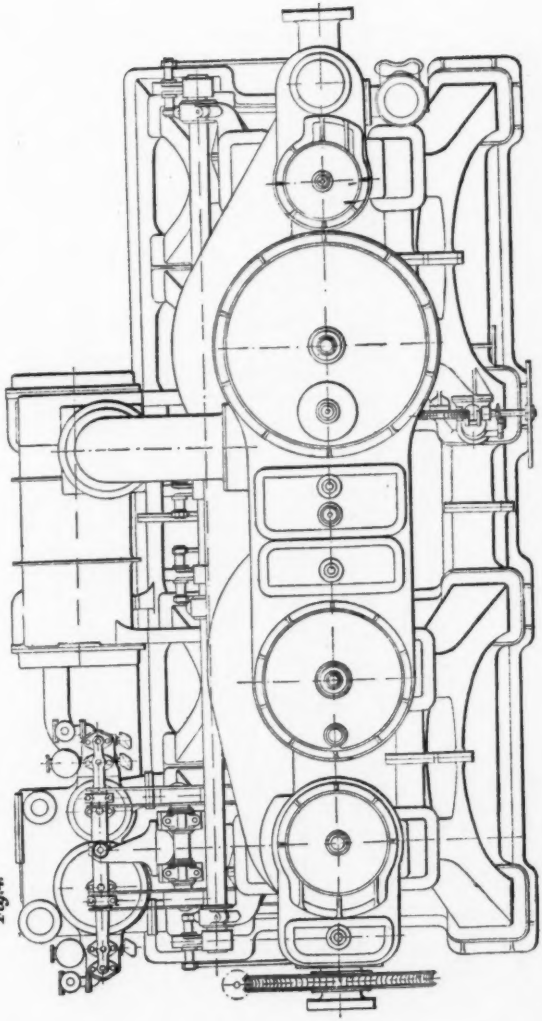


Fig.4

Fig. 7.

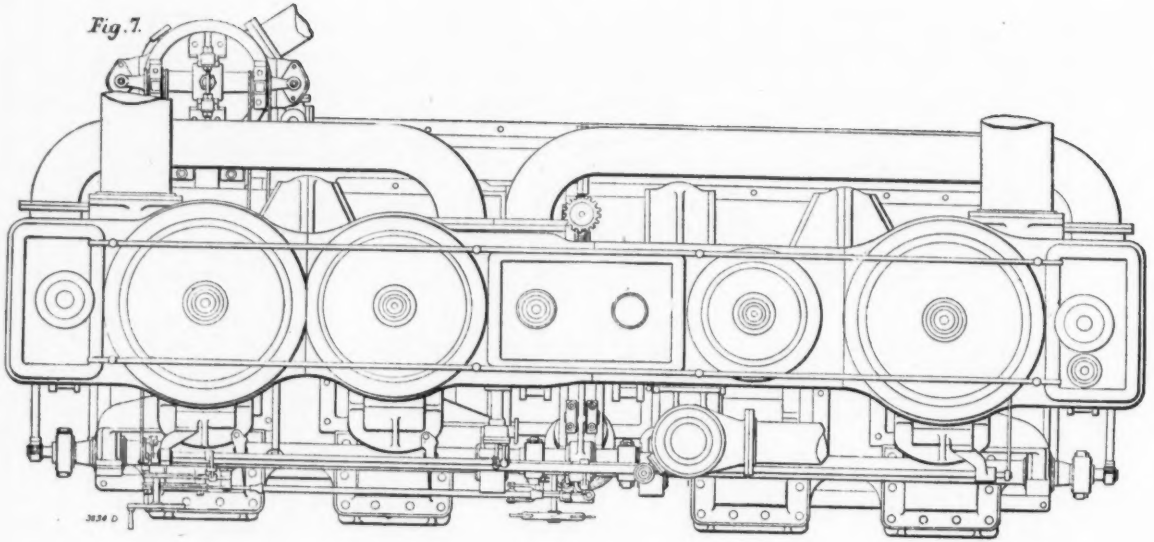
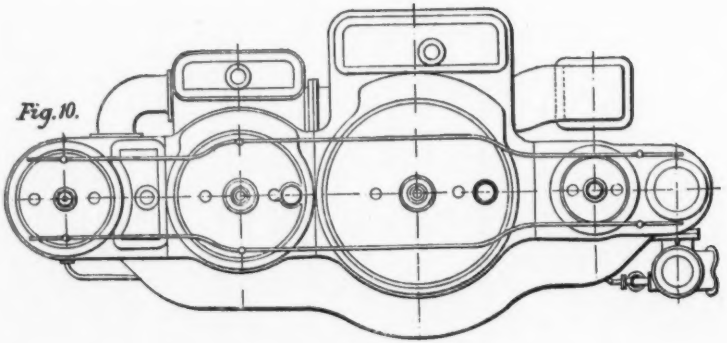


Fig. 10.



& Co.'s quadruple-expansion engines at 215 pounds pressure, that the saving in fuel is 10 per cent., as compared with triple-expansion engines of the same power working at 180 pounds pressure and fitted in sister ships.

But perhaps the most interesting feature of the engines we have been describing is the successful way the system of balancing, now so widely known, has been worked out by Mr. Tweedy. It can be shown that both as regards balancing and the reduction of loss through friction of bearings, the measure of success depends upon the closeness to each other of the fore-and-aft centers of the cranks opposite or nearly opposite, and, further, that the heavier weights should be on the two inside cranks. This condition is fulfilled by the quadruple engines shown by our illustration, and also by the triple-expansion four-crank engines of the *Avon* [described on page 279 of February JOURNAL], and further illustrated by Fig. 7, which we publish this week.

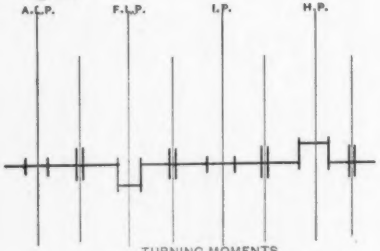
In the quadruple-expansion engines the power developed by each of the four engines is approximately equal, whereas in the four-crank triple-expansion engine, for reasons into which we need not enter here, the power developed by each of the low-pressure cylinders is less than that obtained from the intermediate and high-pressure cylinders, and the parts are proportionately smaller. In the quadruple-expansion engines the required heavier center weight is obtained by the heavier second-intermediate and low-pressure pistons, while in the other case it is obtained by the lighter working parts of the low-pressure engines.

The forces of any given engine tending to produce vibration may be compared in several ways. One method is to make diagrams of the equivalent single forces and couples. The diagrams A, B, C, D and E (Figs. 11 to 25), are curves of such forces of different types of engines, but as the arrangement of cylinders and the sequence of cranks are clearly shown, the diagrams become almost self-explanatory. The upper curves of each set show the tendency of the respective engines to vibrate the ship in a vertical direction, while the lower curves show the corresponding tendency in a horizontal direction. The curves are all drawn to the same scale for engines of the same size running at the same num-

ber of revolutions, and the effects of the valve gear, pumps, and the angularity of the connecting rods are allowed for in all the curves. The ratios of the maximum and minimum turning moments are also given for each set of engines, and it is instructive to notice that in the case of the unbalanced engines, which give turning moments equal to the balanced engines, the vibrating forces are excessive, even compared with other unbalanced engines.

Taking into account the freedom from disturbing forces, the good turning qualities, the simplicity of the arrangement and the accessibility of the parts, and the success of the ships already fitted, there is every prospect that the practice of the immediate future will run more or less on the lines of the types of engines we have illustrated; and we congratulate the able engineers, who have done so much towards the introduction of a better type of engine, amongst them Mr. Otto Schlick, Mr. John Tweedy, Mr. A. F. Yarrow, Mr. Patterson and Mr. C. Jüngermann. It is only an indication of the enterprise of British engineers that already the system has been adopted at this early stage of its development by Messrs. Humphrys, Tennant & Co., Messrs. Harland and Wolff, Messrs. W. Denny and Brothers, Mr. John List, of Sir Donald Currie & Co., and others.

Fig. 20



TURNING MOMENTS
MAX. GREATER THAN MEAN 21%
MIN. LESS THAN MEAN 25%
MAX./MIN. = 1.61

Fig. 21

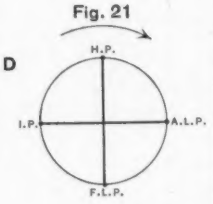
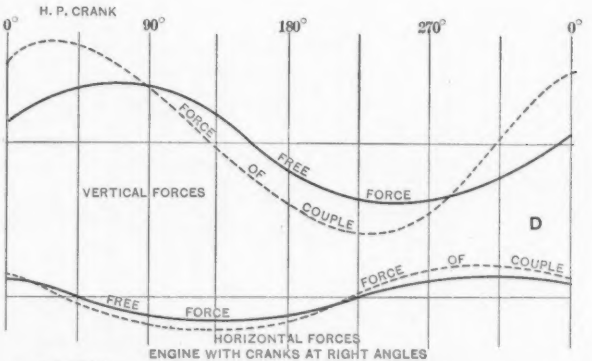
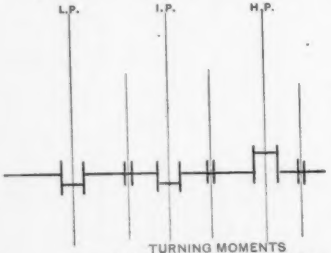


Fig. 22



ENGINE WITH CRANKS AT RIGHT ANGLES

Fig. 23



TURNING MOMENTS
MAX. GREATER THAN MEAN 21%
MIN. LESS THAN MEAN 26%
MAX./MIN. = 1.64

Fig. 24

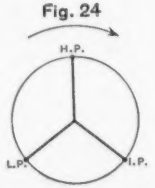
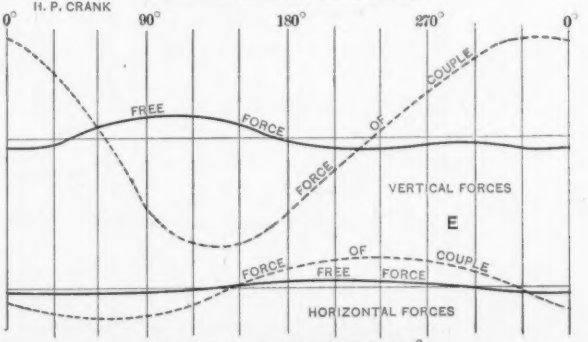
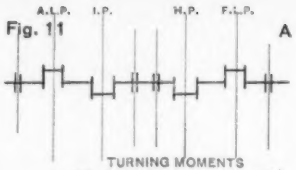


Fig. 25



ENGINE WITH THREE CRANKS AT 120°

Fig. 11



A

TURNING MOMENTS
MAX. GREATER THAN MEAN 22%
MIN. LESS THAN MEAN 23%

$\frac{MAX.}{MIN.} = 1.59$

Fig. 12

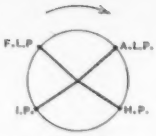
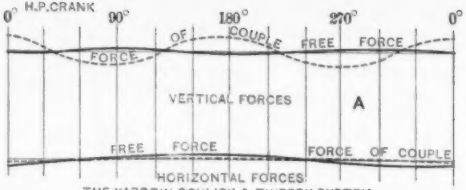
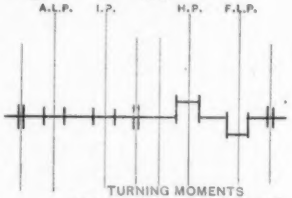


Fig. 13



THE YARROW SCHLICK & TWEEDY SYSTEM

Fig. 14



TURNING MOMENTS
MAX. GREATER THAN MEAN 21%
MIN. LESS THAN MEAN 25%

$\frac{MAX.}{MIN.} = 1.61$

Fig. 15

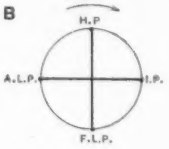
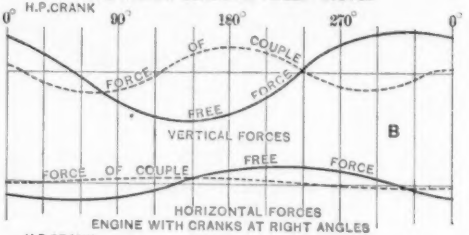
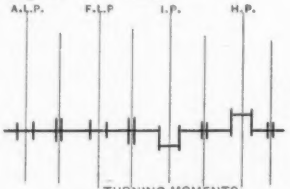


Fig. 16



ENGINE WITH CRANKS AT RIGHT ANGLES

Fig. 17



TURNING MOMENTS
MAX. GREATER THAN MEAN 33%
MIN. LESS THAN MEAN 47%

$\frac{MAX.}{MIN.} = 2.51$

Fig. 18

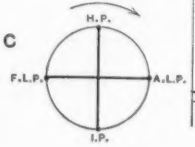
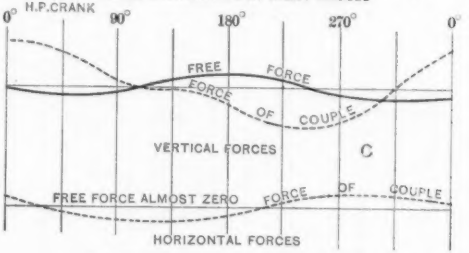


Fig. 19



ENGINE WITH CRANKS AT RIGHT ANGLES

EXPERIMENTS ON THE EFFECT OF DIRECTION OF TURNING IN TWIN SCREWS.

By Mr. R. E. Froude, F. R. S., Associate Member of Council.

[Paper read before the Institution of Naval Architects.]

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1. A few years ago, in the design of certain of Her Majesty's ships, it was deemed desirable, for convenience in arrangement of starting platforms in the engine rooms, that the twin screws should be made to turn inwards, when going ahead, instead of outwards, as usual; in other words, that the starboard screw should be left-handed and the port one right-handed, instead of *vice versa*. Model experiments were therefore made at Haslar to determine whether this arrangement was likely to be detrimental to efficiency, and the results showed that, in the models of the particular ships in question, the arrangement was favorable to efficiency rather than otherwise, the difference being almost within the limits of error of experiment. Afterwards, whenever proposed designs of new ships were tested in model at Haslar, with propellers, it being at that stage generally not decided which way the screws were to turn, it became the practice to try both directions of turning in nearly all cases; and there has thus been accumulated a considerable body of results of model experiments on the comparative efficiency of the two directions of turning, which may be of interest to this Institution.

2. The results are exhibited in detail in the accompanying diagrams, and it may be said of them generally that, as in the first experiments already referred to, they show the efficiency difference to be almost unimportant, but in favor of inward turning rather than the contrary. A few words are requisite in explanation of these diagrams.

3. The uppermost three diagrams show, for each model dealt with, and in comparison for both directions of turning, the famil-

iar "hull-efficiency" elements, viz: the wake and thrust deduction percentages, and the net hull efficiency (viz: the product of the wake and thrust deduction ratios), expressed in the form of percentage excess over unity, defect from unity being shown as negative. The fourth diagram has to do with "rotative" efficiency, or "screw efficiency proper," and requires more explanation.

4. Let us suppose that, in an experiment with the screws working behind model, the speed, revolutions per minute, thrust, and turning moment, are V, R, T and M respectively. Next, suppose an experiment with the same screws, working, not behind model, but in undisturbed water, or "in open," as it is commonly described, at speed V', the ratio $\frac{V}{V'}$ being the "wake" ratio as usually expressed. From the mode of determining wake by model experiments, it follows that, if the revolutions per minute be the same as in the experiment behind model, viz: $= R$, the thrust will also be the same, viz: $= T$. The turning moment also would be the same, viz: $= M$, if the wake disturbance consisted solely of a forward speed, uniform throughout the region of action of the screws. But, in virtue of the other characteristics of the wake disturbance, the turning moment may possibly be slightly different; let us, therefore, term it M', and call the ratio $\frac{M'}{M} = \rho$, say.

5. Now this ratio ρ, namely, the ratio of the turning moment in open to the turning moment behind model, is also the ratio of the rotative efficiency behind model to that in open, since thrust and revolutions per minute are the same for both.* The ratio

* It is true that the speed behind model exceeds that "in open" in the ratio of V to V'; but the efficiency factor $\frac{V}{V'}$ is already taken account of by the wake factor of the hull efficiency. To avoid any confusion, it may be as well here to set forth the whole efficiency account *in extenso*, using the symbols adopted in the text, with the addition of F' to represent the resistance of model without screws working behind. [The resistance with screws working, or augmented resistance, is equal to T the thrust.] We thus get

$$\text{Net total efficiency} = \frac{F'V}{2\pi RM} = \frac{F'}{T} \times \frac{V}{V'} \times \frac{M'}{M} \times \frac{TV'}{2\pi RM'},$$

FULL LINE (LEFT HAND) ORDINATES FOR OUTWARD TURNING; DOTTED (RIGHT HAND) Dº FOR INWARD TURNING.

ought therefore in strictness to be regarded as a third factor of hull efficiency, representing the effect of the wake to modify efficiency by its turbulence or variety of motion, just as the ordinary wake factor represents its effect to increase efficiency by its general motion. This additional factor ρ has generally been treated as unity,† since model experiments showed that it only differed from unity by amounts too small to be satisfactorily measurable for comparisons between individual cases. But in the present investigation it seemed important to take account of it, since the turbulence of wake must probably involve some twisting or rotary motion, which might well affect efficiency differently for the two directions of turning. And this *a priori* view is borne out by the present experiments, which pretty consistently show a significant difference in respect of this ratio ρ between outward and inward turning to the advantage of the latter.

6. The fourth diagram, therefore, shows, under the title of "Relative Rotative Efficiency," this additional factor of efficiency, namely, the ratio ρ, or $\frac{M'}{M}$, in the form of percentage excess over unity, defect from unity being shown negative. The (positive) difference between the ordinates for the two directions of turning, consequently shows (in percentage) advantage of the one direction of turning over the other, on the score of rotative efficiency; and the algebraic sum of this difference and that between the corresponding ordinates of the third diagram, shows the corresponding net balance of percentage advantage in total efficiency, including the hull efficiency as ordinarily reckoned.

7. The experiments with each model extended over a considerable range of speed. The hull efficiency elements themselves varied with speed, as they have generally been found to do, in a

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where the four factors are successively as follows: (1) Thrust deduction, (2) wake, (3) the factor ρ, (4) the rotative efficiency, or "screw efficiency proper" in undisturbed water. In the actual experimenting, it is, of course, not always possible to hit off the intended speeds V and V' with perfect precision, but the correct values of T, M and M' for these intended speeds may be very precisely inferred from the values obtained at the slightly differing speeds of actual experiment.

† On this point see my 1883 paper, Trans. I. N. A., Vol. XXIV, pages 239 and 240.

significant and consistent way. But it did not appear that the relation between the results for the two directions of turning was, in any consistent way, dependent upon speed. Accordingly, in preparing the results which are given in the present paper, the mean results have been taken of all the experiments with each model, irrespective of speed.

8. It will be seen that, of the total list of twenty-one forms for which the model results are given in the accompanying diagrams, Nos. 1 to 3, are battleships; Nos. 4 to 15, cruisers; No. 16, a vessel of specially shallow draught, with Thornycroft pattern of stern; and Nos. 17 to 21, destroyers. No. 16 is singular in showing a hull efficiency materially in excess of unity, but shows nothing exceptional in the relative efficiencies for the two directions of turning. And, in this latter respect, the results in general do not show any clear and consistent difference between the different classes of vessels composing the list. The differences in this respect between the individual vessels, which, in a few cases, are of tangible amount, I am inclined to attribute rather to accidental concurrence of minor errors in the experimenting than to any genuine difference in the conditions.

9. It would seem, therefore, that the safest and most instructive conclusions derivable from these experiments, may be obtained by taking a mean of all the results, irrespective of the classes of vessel which the models represent. We thus get:

Mean excess of thrust deduction percentage, turning inwards, relatively to turning outwards, ... 0.19

Mean excess of wake percentage, turning inwards, relatively to turning outwards, ... 0.65

Mean excess of net hull efficiency percentage, turning inwards, relatively to turning outwards, ... 0.35

Mean excess of relative rotative efficiency percentage, turning inwards, relatively to turning outwards, . . . 1.12

Consequent net balance of percentage advantage, in respect to total efficiency, of turning inwards, relatively to turning outwards, ... 1.49

10. It appears from these figures (and is, indeed, evident from inspection of the diagrams) that:

REFERENCE TABLE FOR DIAGRAM.

Form Nos. 1 to 3, Battleships; Nos. 4 to 15, Cruisers; No. 16, Extreme Shallow-Draught Vessel; Nos. 17 to 21, Destroyers.

Form No.	Dimension constituents.*			Prismatic coefficients.		Remarks.
	Length.	Beam.	Draught.	Fore body.	After body.	
1	4.85	.933	.342	.638	.737	
2	5.09	.966	.339	.600	.684	
3	5.08	.966	.338	.618	.678	
4	5.48	.975	.359	.577	.587	
5	5.48	.975	.359	.561	.573	No. 4 with finer after body, but screws same distance apart.
6	5.48	.975	.359	.561	.573	No. 5 with screws 11 per cent. closer together, giving same clearance as in No. 4.
7	6.34	.888	.334	.568	.628	
8	6.55	.840	.303	.640	.704	Lines approaching Atlantic liner type.
9	6.55	.852	.303	.613	.663	
10	6.55	.852	.303	.593	.668	
11	6.01	.951	.348	.550	.593	
12	5.98	.952	.337	.567	.622	
13	7.19	.863	.323	.533	.620	
14	7.14	.868	.321	.569	.596	
15	6.55	.859	.360	.531	.607	
16	6.35	1.146	.264	.577	.624	Has Thornycroft pattern of stern.
17	9.81	.909	.267	.573	.540	Thornycroft build.
18	9.67	.902	.275	.531	.581	
19	9.66	.979	.268	.535	.605	Laird build.
20	9.83	.983	.261	.505	.544	
21	9.51	.907	.256	.595	.613	Palmer build.

* The figures are the actual dimensions of the ship multiplied by $\frac{.3057}{(\text{displacement in tons})^{\frac{1}{3}}}$; they may equally be regarded as the actual dimensions of an imaginary model of the ship of 1 cubic foot displacement. [See Trans. I. N. A., Vol. XXIX, page 309, sec. 20, and page 312, sec. 28.]

1. Inward turning, as opposed to outward turning, has on the average a slight advantage in respect to net hull efficiency.

2. This advantage is due entirely to an excess in wake, which is partly counteracted, but not completely neutralized by a smaller excess in thrust deduction.

3. In respect of the "relative rotative efficiency," or efficiency factor ρ (*vid. sup.* 4), inward turning has almost invariably the advantage over outward turning, the efficiency factor being generally greater than unity in the former and less than unity in the latter.

11. The amounts in question are, however, all very small, and the mean net efficiency advantage ascribed to inward turning by these results (as above noted) is only 1.5 per cent. Therefore, taking all the circumstances into account, the results hardly do more than afford us good assurance that twin screws may be made to turn inwards instead of outwards, without sacrificing efficiency.

Discussion.

The discussion on Mr. Froude's paper was opened by Mr. Holmes reading a letter from **Mr. John Duncan,** of Port Glasgow. The writer said he was very much interested on reading Mr. Froude's paper to find that the latter's conclusion was opposed to a result obtained with a small twin-screw vessel built by his firm two years ago. Mr. Froude was careful to state that in the models of the particular ships in question the turning of the screws inwards was favorable to efficiency rather than otherwise; and the author further said that later experiments with other models showed the same results as the first. Mr. Froude, the writer continued, made no reference to the particular ships in question, but stated as his final conclusion that the results gave good assurance that twin screws may be made to turn inwards instead of outwards, without sacrificing efficiency. The author thus left it to be inferred that for any vessel, irrespective of form, while it is not safe to count upon an advantage from turning the screws inwards, still the probability is that there would be a slight gain, and at any rate there would be no loss of efficiency. If this conclusion were published as the finding of so eminent an authority as Mr. Froude without some qualification, Mr. Duncan considered it might be seriously misleading, and he, therefore, gave some particulars of the trials of a twin-screw steamer, the *Kia Ora*.

Her dimensions were 120 feet between perpendiculars, by 23 feet beam, by 12 feet 3 inches depth moulded. She was fitted with two sets of triple-expansion engines, which were built with locomotive guides, so that the engines might be turned either way to go ahead according to the screws fitted on the shafts. At the vessel's trials the draughts were 5 feet 7 inches forward and 6 feet 1 inch aft to bottom of keel, which was 5 inches deep, and the displacement was 280 tons. At this condition of trim and displacement a speed of 10 knots was guaranteed.

The trials were between the Cloch and Cumbrae lights on the Clyde. The first trial was on Saturday, June 6, 1896, and the mean speed of four runs, with the screws running inwards was 9.11 knots. The vessel was brought back to the yard and the propellers shifted to opposite shafts; no other alteration whatever was made on the machinery. In the same trim, on Monday, the 8th, the vessel was again run four times on the course, the screws on this occasion turning outwards. A mean speed of 10.34 knots was reached, or 1.23 knots more than on the Saturday's run. This was a considerable gain in favor of turning the screws outwards. There was plenty of steam on both occasions, and the engines were fully opened out. The mean revolutions were practically the same on both trials. The weather conditions were good on both days.

Mr. Macfarlane Gray pointed out that the experiments made by Mr. Duncan did not throw much light on the problem in the absence of indicator diagrams. It was not at all improbable that the engines might have been less efficient when reversed than when running with the link in the ordinary or "go-ahead" position. He thought Mr. Duncan should be invited to send indicator diagrams.

Mr. Watkins was somewhat surprised at the paper. He had anticipated that the meeting would have been told how great was the difference in efficiency between inward and outward turning of the twin screw, instead of being informed that there was practically nothing to choose. He narrated his experience with a twin-screw tug, which could not be turned round in the whole breadth of the River Thames when the screws were turning inward, but by alteration in this respect was made to turn very easily. Mr. Froude here remarked that he had not dealt with the question of turning at all.

Sir William White would not challenge the accuracy of what Mr. Watkins had said, but he had had large experience with screws turning inwards, and had found no difficulty in regard to steering. He would remind the meeting that there were many other features in the design of a ship besides the turning of the screws which might affect the steering, and before saying anything upon that subject in regard to results obtained with any particular vessel, it would be necessary to know the shape of the stern. The subject before the meeting, however, was not that of steering, but whether any sacrifice in propulsive efficiency

was likely to be made by making screws turn inwards. The results of Mr. Froude's investigations showed that no detriment need be anticipated in that respect. The Admiralty had put that question to the test, and had found that the propulsive efficiency was not only high with inward-turning screws, but that the vessels also answered their helm readily. There were, as is well known, advantages gained in the arrangement of the engine room with inward-turning screws. In regard to Mr. Duncan's letter, the difference of the two arrangements appeared enormous, and he was sorry the writer of the letter was not present. Mr. Gray had referred to the disturbing result likely to arise through reversing the engines. Some information should also be given as to the form of the stern of the vessel. He was sure that there was something beyond the direction of the screws which affected the results.

Mr. J. I. Thornycroft referred to a vessel with a Thornycroft stern mentioned by the author. He thought the facts stated pointed to a quantity of water being set in motion and coming to the propeller when moving with the ship.

Mr. Sidney Barnaby asked Mr. Froude if he had tried screws slightly overlapping and running in the same direction. Mr. Normand thought that improved efficiency could be obtained in this way.

Mr. Froude, replying to Mr. Barnaby's question first, said he had tried screws running in the same direction and almost touching, but had been unable to find that any results differing from those ordinarily obtained were produced. In regard to many of the criticisms on the paper, he would remark that the experiments narrated only included twenty-one forms of ship. Some of these differed widely, but, nevertheless, there were other forms, therefore the results could not be taken as exhaustive: the paper only pretended to put on record the observations obtained on certain experiments. It must also be remembered that these were model experiments, and corrections might be necessary in transferring their results to what might be obtained with real ships.

THE UNITED STATES TORPEDO BOATS *TALBOT* AND *GWIN.*

By Passed Assistant Engineer M. A. Anderson, U. S. Navy, and Assistant Naval Constructor H. G. Gillmor, U. S. Navy.

The *Talbot* and *Gwin* are steel single-screw torpedo boats built by the Herreshoff Manufacturing Co., from designs and specifications prepared by them. Their principal dimensions are:

Length on W. L. at trial, feet and inches		99–6
Length over all, feet		100
Beam at deck, feet and inches		12–6
Beam on water line, feet		12
Depth amidships, keel to center of deck, feet and inches		8–3
Draft (on trial)	Forward, feet and inches	2–1
	Aft, feet and inches	5–6½
	Mean, feet and inches	3–9¾
Displacement, tons		45¾
Tons per inch at trial water line		1.87
Moment to alter trim one inch, ton feet		9.2
Area trial water plane, square feet		787
Center of gravity, trial water plane abaft midship section, feet		3.13
Center of buoyancy above bottom of keel, feet		2.31
Center of buoyancy abaft midship section, feet		1.80
Center of gravity above keel, feet		4.9
Transverse metacenter above center of buoyancy (B.M.), feet		3.93
Longitudinal metacenter above center of buoyancy (B.M.), feet		241.
Transverse metacentric height (G.M.), feet		1.34
Longitudinal metacentric height (G.M.), feet		238.4
Block coefficient for displacement		.413
Midship section coefficient		.743
Coefficient of trial W.L.		.659
Wetted surface to trial W.L., square feet		1,055
Number of frames		78

These vessels are of an unusually light construction, though amply strong for the service for which they are intended. The material is steel of tensile strength of 55,000 pounds per square inch for the plates and 60,000 pounds for the shapes, with an elon-

gation of 28 per cent. in 8 inches. The plating of the shell of the hull varies in thickness from 6½/40 inches for the keel to 3½/40 inches at the ends for the upper strakes. All the edges are lapped and single riveted, while the butts are strapped and double riveted. Edges and butts are made tight by caulking without the use of canvas or paper. The plating of the bulkheads is 3½/40 to $\frac{2}{40}$ inches in thickness, with canvas in all joints to secure water-tightness. The transverse frames and deck beams are angle bulb steel 1¾ inches by 1⅛ inches by 2.63 pounds amidships, and 1½ inches by 1 inch by 1.27 pounds at the ends, spaced 15 inches apart. The vertical keel is made up of two 1¾ inches by 2½ inches by 2.56 pounds angles riveted back to back. The floor plates are continuous across the boat, being notched over the vertical keel.

The vessels are divided transversely by five complete water-tight bulkheads and by three partial bulkheads, which are made to be water-tight well above the water line.

The boats have accommodations for one officer, two petty officers and eight men. The petty officers and men are quartered aft and the commanding officer forward.

The rudders are of the same form and hung in the same manner as that for the *Morris*, the area being about 14 square feet. The boats may be steered by hand from the forward conning tower or the after conning tower, and by steam from the forward conning tower, or, as a last resort, by means of a spare tiller shipping upon the rudder stock above the main deck, and relieving tackles. The steering engines are in all respects like the steering engine of the *Morris*. The steering engine may also be used for working the windlass and capstan, the power being transmitted by a sprocket wheel and chain gear.

To rid the compartments of all the ordinary accumulations of water, there is one steam siphon ejector in each compartment excepting the engine and boiler compartments, which have two each. As in the *Morris*, the smaller boats have arrangements for taking the condensing water through the main drain from any compartment which may have become so damaged as to admit large quantities of water.

The armament of these boats consists of one 1-pounder gun mounted on the after conning tower and two torpedo tubes for the short 18-inch torpedo. The two torpedo tubes are mounted on the middle line, one at the stern and one between the conning tower and the funnel. Both may be fired upon either side. The boats carry stowed in the tubes one torpedo for each tube.

The *Talbot* and *Gwin* were tried on the same day, March 3, 1898, over a course in Narragansett Bay. Ranges on Conanicut and Rose Islands marked distances of six and seven nautical miles, respectively, from a range at Sand's Point. The depth of water was about ten fathoms. The weather was hazy with a smooth sea.

The contracts required the boats to maintain a speed of 20 knots an hour for a period of two consecutive hours. It was decided to made two runs each way over the seven nautical miles from Sand's Point to Rose Island and one run each way over the six nautical miles from Sand's Point to Conanicut range, making in all 40 nautical miles which, with the time occupied in the turns, would make up the two hours required. The results of the several runs were as follows:

TALBOT.

Runs.	Elapsed time.		Distance.	Speed.
	Minutes.	*Seconds.*	*Nautical miles.*	*Knots.*
First S.	19	40	7	21.3
Second N.	20	15	7	20.7
Third S.	19	47	7	21.2
Fourth N.	20	11	7	20.8
Fifth S.	16	21	6	22.0
Sixth N.	17	24	6	20.7

GWIN.

Runs.	Elapsed time.		Distance.	Speed.
	Minutes.	*Seconds.*	*Nautical miles.*	*Knots.*
First S.	19	23	7	21.6
Second N.	21	11	7	19.8
Third S.	19	11	7	21.9
Fourth N.	20	45	7	20.2
Fifth S.	16	26	6	21.9
Sixth N.	17	49	6	20.2

The boats carried on trial, in addition to their completed hulls, machinery, and spare parts, a load of 10.48 tons, made up of 3.3 tons of coal, 2.52 tons in crew, equipment, etc., 1.78 tons in ordnance and ordnance outfit and 2.88 tons in lead ballast, representing the weights of articles required but not on board during the trial. When so loaded their mean draught was 3 feet 9¾ inches, corresponding to a displacement of about 45¾ tons.

Observations of pressure, revolutions, etc., taken at intervals of fifteen minutes are given below:

TALBOT.

Time.	Steam pressures above atmosphere.				Vacuum.	Air pressure.	Revolutions.
	Boiler.	H.P. Cyl	I.P.R.	L.P.R.			
					Inches.	*Inches.*	
Start	200	198	79	22.5	24.25	2.75	.....
¼ hour	205	202	78	22.	23.5	2.75	442.66
½ hour	198	196	78	22.	22.75	3.25	430.66
¾ hour	192	186	80	22.	23.25	2.75	445.33
1 hour	200	197	79	22.	22.25	3.5	437.33
1¼ hours	202	200	79	21.5	23.5	3.5	420.00
1½ hours	202	198	78	21.5	24.25	3.75	434.00
1¾ hours	204	202	78	21.5	24.	3.75	459.33
2 hours	195	192	78	21.5	24.25	3.75	440.66
Mean	199.8	196.8	78.5	21.8	23.4	3.3	.....

GWIN.

Time.	Steam pressures above atmosphere.				Vacuum.	Air pressure.	Revolutions.
	Boiler.	H.P.Cyl.	I.P.R.	L.P.R.			
					Inches.	*Inches.*	
Start	194	190	82	23	25	3	.....
¼ hour	207	206	84	23	25	2.5	446.4
½ hour	201	201	82	22	24.75	3	446.00
¾ hour	212	210	86	21	24.25	3	443.6
1 hour	210	207	85	20.5	24.5	3	449.33
1¼ hours	207	204	83	20	24.5	3	441.33
1½ hours	207	204	85	20	24.5	3	437.33
1¾ hours	211	208	85	19	24.25	3	448.00
2 hours	208	206	84	23.5	24	3	446.66
Mean	206	204	84	21.3	24.6	2.94	.....

	Talbot.	*Gwin.*
Duration of trial, hours, minutes and seconds	2·5·59	2·6·18
Total number of revolutions of engines	55,168	55,865
Mean number of revolutions per minute	437.9	442.3
Total time during which vessel was on the course, hours, minutes and seconds	1·53·38	1·54·45
Total number of revolutions during this time	49,934	50,922
Mean number of revolutions per minute	439.4	443.8
Mean speed of vessel, corrected for tidal current	21.15	20.88
Mean slip of screw, per cent	19.4	23.84
Mean number of revolutions of blower	933	945
Mean number of revolutions of air and feed pumps	122	118
Mean number of revolutions of circulating pump	490	500
Temperature of sea water, degrees	38	38
Temperature of feed water, degrees	116	110

The change of trim of the boats at these speeds amounted to about 41 inches. The steering of the boats by steam was very easy and effective. Owing to the action of the single screw upon the rudder, which is close to and just behind it, some helm had to be carried in order to keep the boats on the course. On account of the necessity of holding the rudder at this angle, the steering of the boats by hand from the forward or after conning tower required considerable effort on the part of the helmsman, though it could be satisfactorily done. With the steam gear it required four seconds to put the helm from amidships to hard over when going at full speed.

The engine is of the vertical, inverted, direct-acting, three-cylinder, triple-expansion type with cranks 120 degrees apart. The cylinders are not jacketed, but lagged with asbestos, with an outer covering of Russia iron. The H.P. and I.P. cylinders have each one, and the L.P. cylinder two piston valves, which are worked by a valve-motion shaft parallel to the main shaft, and so geared to it that the revolutions are equal but in opposite directions.

The engine was designed to develop 850 I.H.P. at 400 revolutions per minute with a boiler pressure of 225 pounds.

The engine bed consists of two steel channels placed fore and aft and parallel, and supported on foundations built into the boat. These channels are connected by four cross yokes of cast steel, which also form the engine bearings—the after one being fitted

to take part of the thrust. To these are secured the vertical forged steel stanchions, which support the cylinders. These stanchions, or columns, are stiffened by diagonal braces. The crosshead guides are of forged steel, bolted at top and bottom to horizontal guide rails secured to the columns; they have no water circulation.

The piston rods and valve stems are oil tempered and annealed. The L.P. piston rod is bored out axially. The pistons are of cast steel fitted with cast-iron packing rings set out by steel springs. The piston rods are screwed into the pistons and the ends are riveted over; they are also screwed into the crossheads. The valves are of cast steel with cast-iron packing rings set out by steam pressure. The piston rod and valve-stem stuffing boxes are adapted to be adjusted when the engine is in motion, and are packed with Selden's packing, treated with black lead.

The connecting rods are double, consisting of two parallel flat pieces secured at their lower ends to the crank-pin brasses and united at their upper ends by the wrist pins, which are shrunk in.

The main thrust bearing is attached to the engine bed and is adjustable. It consists of two cast-steel blocks lined with white metal and fitted with a water jacket connected with the injection and discharge pipes of the condenser.

DATA OF MAIN ENGINE.

Number of cylinders	3
Diameter of H.P cylinder, inches	12½
Diameter of I.P. cylinder, inches	18
Diameter of L.P. cylinder, inches	25
Stroke, inches	13½
Diameter of H.P. and I.P. piston rods, inches	1⅞
Diameter of L.P. piston rod, inside, inches, 1½; outside, inches	2⅛
Length of connecting rods, center to center, inches	33¼
Crank and thrust shafts (one piece, solid), length over all, feet and inches	8–11½
Diameter, inches	5⅛
Crank pins, diameter, inches	5⅛
Crank pins, length, inches	8
Valve shaft, diameter, inches	2½
H.P. valve, diameter, inches	6¼
I.P. valve, diameter, inches	8
L.P. valve, diameter, inches	8

Condenser.—There is one surface condenser made of sheet copper. The heads are conical, and continue down through the bottom of the boat, forming scoops for the circulating water. The forward scoop has a strainer.

In the forward head is a turbine driven by a small single, vertical engine, $3\frac{1}{2}$ inches $\times$ $3\frac{1}{2}$ inches. The tube sheets are of Tobin bronze, and the tubes are expanded into them.

Number of tubes	596
Length between tube sheets, feet and inches	6–3
Diameter of tubes outside, inch	$\frac{5}{8}$
Thickness B.W.G.	18
Cooling surface, square feet	600

Air and Feed Pumps.—There are three single-acting vertical-bucket air pumps worked from a cast-steel shaft having cranks 120 degrees apart. On a continuation of this shaft are three vertical single acting plunger feed pumps. The engine is two cylinder and simple, with cylinders, $3\frac{1}{2}$ inches diameter and 5 inches stroke, geared down to the pump shaft in a ratio of 3.2 to 1. It is controlled by a ball governor. On top of the air-pump casing, and enclosing the shaft, is a sheet-brass tank, which forms the hot well and also the feed tank.

Propeller.—The propeller is in one piece, of manganese bronze. It has three blades and is of somewhat irregular pitch, approximating to a true screw. The irregularity in pitch is due to the fact that the thickness, added for strength, is distributed equally on backing and go-ahead surfaces, with a view to making the screw more efficient in backing. It is not unlike the old "Bureau" or "Isherwood" screw in shape. The diameter is 4 feet 8 inches, and the pitch is 6.25 feet.

Auxiliaries.—The forced draft is supplied by a 36-inch fan driven by a single-cylinder vertical engine, 4 inches $\times$ 4 inches. The engine is on the engine-room side of the bulkhead and the blower on the fire-room side.

In the fire room is a vertical, duplex Blake pump, 5 inches and 3 inches $\times$ 4 inches, which delivers to the boiler only. It can take water from the hot well, from the supply tanks, or from the sea.

In the engine room is a horizontal Marsh pump which can

deliver to the boiler, to a hose connection on deck, or overboard, and can take water from the main drain, from the sea and from the supply tanks.

There are two bilge ejectors in the engine room and two in the fire room, each having an estimated capacity of twenty tons per hour. A Rand air compressor for the torpedoes is installed in the engine room.

BOILER.

The boiler is of the Normand type, consisting of an upper steam drum connected to two lower water drums by drawn steel tubes, and the back ends by down pipes. The tubes enter the steam drum below the water level. The water drums and down pipes are welded steel tubes. The steam drum is made of two semi-cylindrical steel plates with cast-steel ends. The boiler is fitted with a quick-closing stop valve, which can be operated from the fire room or from the deck.

Steam drum, length, feet and inches	10– 6
Steam drum, diameter (inside), inches	32
Water drum, length, feet and inches	10– 6
Water drum, diameter (inside), inches	16
Down pipes, length, feet and inches	3–10
Down pipes, diameter (inside), inches	10
Tubes, number, 1,293; diameter, 1⅛ inches outside; B.W.G.	18
Total heating surface, square feet	1,870
Grate surface, square feet	38
Number of furnaces, 1; length, 8 feet; width, feet and inches	4–9

MACHINERY WEIGHTS.

	Talbot. Pounds.	*Gwin.* Pounds.
Main engine cylinders,	3,591	3,596
Shafting,	3,636	3,629
Main engine, framing and bearings,	2,476	2,495
Reciprocating parts,	724	724
Main engine valve gear,	615	615
Main condenser,	1,881	1,885
Main air, circulating and feed pumps,	1,471	1,500
Propeller,	390	402
Boiler,	9,296	9,501

	Tabot. Pounds.	*Gwin.* Pounds.
Boiler fittings,	3,671	3,665
Smoke pipe and casing,	1,239	1,243
Steam and exhaust pipes and valves,	1,173	1,161
Suction and discharge pipes and valves,	961	956
Lagging and clothing,	458	459
Flooring, gratings, etc.,	841	673
Auxiliaries,	984	978
Fittings and gear,	1,038	1,059
Water,	8,233	8,233
Stores, tools, etc.,	303	303
Miscellaneous machinery,	395	395

Weight of propelling machinery, per designed I.H.P. (850), *Talbot*, 50.2 pounds; *Gwin*, 50.3 pounds.

THE U. S. TORPEDO BOAT *MORRIS.*

By Assistant Naval Constructor H. G. Gillmor, U. S. Navy, and Passed Assistant Engineer M. A. Anderson, U. S. Navy.

The *Morris* is a steel, twin-screw, sea-going torpedo boat, built by the Herreshoff Manufacturing Company, of Bristol, Rhode Island, from a design and specifications prepared by them. Her principal hull dimensions are:

Length on W.L., at trial, feet and inches		138–6
Length over all, feet and inches		147–0
Beam at deck, feet and inches		15–6
Beam at water line, about, feet and inches		15–0
Draft (on trial),	Forward, feet and inches	2–9
	Aft, feet and inches	5–9
	Mean, feet and inches	4–3
Displacement (on trial), tons		98
Displacement (ready for sea), about, tons		145
Tons per inch at trial, water line		3.4
Moment to alter trim one inch, ton feet		24.6
Area of trial water plane, square feet		1,447
Center of gravity of trial water plane abaft midship section, feet		5.35
Center of buoyancy above bottom of keel, feet		2.84
Center of buoyancy abaft midship section, feet		2.99
Center of gravity above keel, feet		5.95
Transverse metacenter above center of buoyancy (B.M.), feet		5.33
Longitudinal metacenter above center of buoyancy (B.M), feet		391
Transverse metacentric height (G.M.), feet		2.22
Longitudinal metacentric height (G.M.), feet		387.9
Block coefficient for displacement		.425
Midship section coefficient		.755
Coefficient of trial W.L.		.687
Wetted surface to trial W.L., square feet		1,912
Number of frames		105

Like most vessels of this character, the *Morris* has a rocker keel and is very much cut up aft. The after sections have a broad V form very different from the flat sections commonly employed in vessels of this class. The form of the bow is novel.

The stem is curved and is given a great deal of rake, so that the bow projects some eight feet beyond the intersection of the stem and the normal water line. On account of the raking stem and the change of trim, the boat runs at high speed upon a considerably reduced water line length. The designer believes that the form of bow given to this boat will improve her sea qualities and make her freer from the tendency to pitch and cut through seas.

The vessel is of the light construction which characterizes this class of work, the material being steel of a tensile strength of 55,000 pounds per square inch for the plates, and 60,000 pounds for the shapes, with an elongation of 28 per cent. in 8 inches. The plating of the shell of the hull varies in thickness from $\frac{8}{40}$ inch for the keel amidships to $\frac{4}{40}$ inch for end plating of the upper strakes. The edge connections are single riveted, and the butts double riveted, except in the case of the keel and sheer strake, the butts of which are double riveted. All joints and seams are made tight by caulking without the use of canvas or paper. The plating of the bulkheads varies from $\frac{4}{40}$ inch for the lower strake to $2\frac{1}{2}/40$ inches for the top, both edges and butts being lapped and riveted. Canvas soaked in red lead is used in the seams to insure water tightness. The transverse frames and deck beams are of bulb angle steel, $2\frac{1}{2} \times 1\frac{1}{2} \times 2.66$ pounds per foot amidships and $2\frac{1}{8} \times 1\frac{5}{16} \times 2.2$ pounds at ends, spaced $16\frac{1}{2}$ inches apart, center to center. The connection between the deck beams and frames is made by a flanged bracket plate in lieu of a beam knee.

The vessel is divided transversely by ten bulkheads into eleven compartments, there being no doors or openings in any of these bulkheads except the first and last. Access to any of the principal compartments may be obtained only from the deck. The coal bunkers are abreast the boilers, extending between the bulkheads of the boiler room. A transverse bulkhead in each side subdivides into four complete water-tight compartments, each with a sliding water-tight door.

The boat has accommodations for a crew of twenty-four petty officers and men and four officers. Twenty of the crew are quar-

tered in the two after compartments and provision is made for four petty officers in a compartment just forward of the boiler space. The quarters for the officers are forward, access to them being provided through the forward conning tower. They consist of two state rooms with fixed bunks for the commanding officer and the engineer officer, a ward room with a large transom and a bunk, a pantry and a bathroom.

In the compartment next forward of the officers' quarters, to which there is access from the turtle back, is a windlass and on the deck above a capstan driven by a two-cylinder simple steam engine, cylinders $3\frac{1}{2}$ inches in diameter, with a stroke of $3\frac{1}{2}$ inches. It has proved fully capable of handling rapidly and efficiently the 120-pound anchors and wire cables of the boat.

The rudder is of the partially balanced type of an area of about 20 square feet, with a little more than one-fifth the area forward of the axis. It projects entirely below the hull, so that the pressure upon it tends to counteract the tendency to heel in turning, its weight being taken upon a bearing built into the deck. There is no lower bearing, all the lateral stress being taken upon the heavy stuffing box, through which the stock passes, and upon the upper bearing.

The boat may be steered by hand or steam from the forward conning tower; by hand, at a steering station on deck just forward of the after conning tower, and by means of a spare tiller and relieving tackles on deck aft. The steam steering engine is in the forward conning tower and is a duplicate of the capstan and windlass engine, except for the reversing valve, with two cylinders each $3\frac{1}{2}$ inches in diameter with a $3\frac{1}{2}$-inch stroke, and is balanced. The efficiency of the balancing may be judged from the fact that it was run in the ship at 1,700 revolutions per minute, standing upon an iron table to which it was not secured. The engine actuates a rack and pinion through a worm gear giving a high power ratio, so that the same rack and pinion are used for both hand and steam steering. The valve is actuated directly by the hand wheel, and is returned to the closed position by the motion of the engine, so that the engine moves only while the steering wheel is being moved. Only four turns of the hand wheel are necessary to put the helm

from amidships hard over, so that quick steering is assured. The weight of the complete steering engine, rack, hand wheel, etc., is only 181 pounds.

To rid the compartments of any ordinary accumulation of water in them, there is provided a syphon ejector for each of the three forward compartments and two in each of the other compartments excepting that for the boiler, which has three. To handle large volumes of water, such as might find access to the vessel through the bilging of any compartment, arrangement is made so that the condensing water may be taken by the circulating pump through the main drain, which has suction branches in all the principal compartments.

The armament consists of four 1-pounder guns and three torpedo tubes for the long 18-inch torpedo. The guns are all mounted on the middle line—one on the turtle back forward of the forward conning tower, one between the two funnels, one just forward of the after conning tower, and one just aft of it. The three torpedo tubes are mounted—one outboard on the port side just clear of the bounding bulkhead of the turtle back, one outboard on the starboard side just over the bulkhead between the engine and boiler rooms, and one aft on the middle line. The torpedoes are to be carried in the tubes and provisions are made for stowing two torpedoes within and at the base of the after conning tower.

The trial of the *Morris* took place over a course in Narragansett Bay on the 17th of April. Ranges on Rose Island and Fort Adams marked distances of seven and eight nautical miles, respectively, from the upper range at Sand's Point. The depth of water on the course was about 10 fathoms. The weather was good and the sea smooth.

The contract required the boat to maintain a speed of 22½ knots per hour for a period of two hours. It was decided to run once each way over the eight nautical miles between Sand's Point and Fort Adams, and twice each way over the seven nautical miles between Sand's Point and Rose Island, making a total distance of 44 nautical miles, to cover which distance, including the time necessary to make the turns at the ends of the

runs, required a little more than the two hours specified. The boat carried on trial, in addition to her completed hull, machinery and spare parts, a load of 20 tons made up of 6 tons of coal, 6.4 tons representing ammunition, etc., and 7.6 tons representing boat's crew, equipment, etc. When so loaded, her mean draught was 4 feet 3 inches, corresponding to a displacement of about 98 tons. The results for the several runs were as follows:

Runs.	Elapsed time.		Distance.	Speed.
	Minutes.	*Seconds.*	*Nautical Miles.*	*Knots.*
First S.	19	20	8	24.8
Second N.	20	23	8	23.5
Third S.	17	22	7	24.2
Fourth N.	17	50	7	23.5
Fifth S.	17	26	7	24.1
Sixth N.	17	34	7	23.9

The results of observations of pressure, revolutions, etc., are given in the table below:

Duration of trial	2 hours 4 minutes 55 seconds.	
	Starboard.	*Port.*
Total revolutions of engines	56,214	56,363
Mean revolutions per minute	451.4	452.5
Mean pressure at engine, pounds	191	192
Mean pressure, first receiver, pounds	79.3	79.1
Mean pressure, second receiver, pounds	20.4	21.7
Mean vacuum, inches	25	
Mean pressure at boilers, pounds	195.5	
Maximum pressure at boilers, pounds	205	
Mean air pressure, inches	$1\frac{3}{4}$	
Maximum air pressure, inches	$2\frac{1}{4}$	
Temperature feed water, degrees Fahrenheit	85	
Temperature engine room, degrees Fahrenheit	88	
Temperature fire room, degrees Fahrenheit	85	
Temperature of outside air, degrees Fahrenheit	70	
Revolutions of air and feed pump	120	

The circulating pump was not run, necessary circulation being provided by a scoop at the injection inlet.

The mean speed for the entire six runs, corrected for the tide from observations made from the *Stiletto*, *Talbot* and *Gwin*, which

were stationed on the course for the purpose, was 24 knots or 1½ knots in excess of the contract requirements.

The change of trim of the boat at this speed amounted to about 50 inches. She traveled on the back slope of a wave with a normal disturbance of the surface of the water. The vibrations while considerable were not excessive. The steam steering gear worked admirably at all times, the turning at the ends of the runs demonstrating its efficiency. Four seconds are necessary to put the helm from amidships to hard over at full speed.

The *Morris* has two main engines precisely like those of the *Talbot* and *Gwin*, described in another article in this issue, except that they are right and left. The boilers are substantially the same, being slightly shorter and wider, but having longer tubes. Grate surface of each, 40 square feet; heating surface, 2,002 square feet.

There is one main condenser, made as described for *Talbot* and *Gwin*.

Number of tubes, 1,167. Dimensions, as for *Talbot* and *Gwin*. Length between tube sheets, 6 feet 4 inches. Cooling surface, 1,195 square feet.

The air and feed pumps are like those for *Talbot* and *Gwin*, except that the engine is slightly larger and the feed pump has double the capacity. A Baird evaporator and distiller are installed in the engine room, also a 50-light dynamo and a Rand air compressor.

In the fire room is a blower having a horizontal fan, 51 inches diameter, secured to under side of deck, driven by a horizontal single engine 4 × 4.

There are also in fire room two Blake pumps and one Marsh pump of the same sizes as for *Talbot* and *Gwin*.

The boilers are placed fore-and-aft and facing each other, with common fire room.

A telegraph is fitted for communicating between engine and fire rooms.

Each boiler has a ball-float feed regulator to keep water at same level in each.

There are two bilge ejectors in engine room and three in fire room.

MACHINERY WEIGHTS OF *MORRIS*.

	Pounds.
Main engine cylinders,	7,030
Shafting,	9,087
Main engine framing and bearings,	4,904
Reciprocating parts of main engines,	1,454
Main engine valve gear,	1,234
Main condenser,	3,331
Main air and circulating pumps,	1,901
Propellers,	827
Boilers,	20,138
Boiler fittings,	8,564
Smoke pipes and casings,	2,969
Steam and exhaust pipes and valves,	2,521
Suction and discharge pipes and valves,	1,425
Lagging and clothing,	996
Flooring, gratings, etc.,	1,618
Auxiliaries,	1,415
Fittings and gear,	1,521
Water,	17,885
Stores, tools, etc.,	370
Miscellaneous machinery,	1,600

Weight of propelling machinery per maximum designed power (1,750), 51.9 pounds.

NOTES.

LIGHT-DRAUGHT STEAMERS.

In a communication in our February number, by Mr. Charles Ward, on "Speed and Power Trials of a Light-Draught Steam Launch," certain questions are asked in connection with some vessels recently built by Thornycroft and Yarrow for the Nile expedition. The vessels are practically similar, but there appears to be a discrepancy in the power required to drive them, the Thornycroft boat being fitted with two guide-blade turbine propellers and the Yarrow boat being fitted with two ordinary screw propellers of special proportions, working in tunnels.

We have obtained from a thoroughly reliable source the exact results, which are of special scientific interest, because these vessels are probably the first two examples of these competitive systems of propulsion tried under parallel conditions. The *Melik* was built by Thornycroft and the *Sultan* by Yarrow. The dimensions of both boats are 145 feet in length by 24 feet 6 inches beam; but the lines of the *Melik* are finer than those of the *Sultan*, the displacements being, respectively, 140.4 tons, with a draught of $24\frac{1}{2}$ inches for the *Melik*, and 146 tons displacement for the *Sultan*, with a draught of $23\frac{1}{2}$ inches.

The speed and power of the *Melik* were 11.97 knots with 461 I.H.P., and of the *Sultan* 11.4 knots with 473 I.H.P., consequently it will be seen that the *Melik* developed 12 H.P. less than the *Sultan* and had a speed of .57 knots greater. Considering that the *Melik* had less displacement and finer lines than the *Sultan*, it may be roughly taken that the results of the two systems when going ahead are practically equally good. It must, however, not be lost sight of, in making this comparison, that the turbine propeller is utterly inefficient for going astern or for stopping headway, while with the Yarrow boat a speed going astern was obtained of about two-thirds of that going

ahead. Considering that the efficiency going ahead is practically the same with the two systems of propulsion, and that the turbine system is most inefficient when going astern, the ordinary screw is clearly the better and certainly the simpler plan for this class of vessel.

BRAZED COPPER STEAM PIPES.

[Reprinted from "Engineering."]

An investigation recently made by Professor Arnold, of Sheffield, on behalf of the Committee of Lloyd's Register of British and Foreign Shipping, appears to point to a new danger in the use of large copper steam pipes. This practice grew up in the days of low steam pressures, and proved for many years very successful. Copper is a metal which has extraordinary powers of standing punishment, as is shown by the comparatively excellent results obtained with it as a material for stay bolts. It could thus be used in a steam pipe with a much less liberality of curvature than the early engine builders found necessary to provide for expansion when cast iron was employed for the purpose. Space being always at a premium on board ship, the use of copper pipes in this way resulted quite naturally, particularly as an expansion joint of the stuffing-box type failed to be satisfactory with the older types of packing material. Unfortunately, however, the strength of copper and, still worse, its alloys, falls off somewhat rapidly with increasing temperatures.

Whether the capacity of these materials for taking punishment is equally affected is another matter, since so far there has as yet been no condition recognized in copper corresponding to that arising in the case of steel when warmed to a blue heat. In fact, some recent experiments made by Professor Warren, though not altogether concordant, *inter se*, show no serious falling off in the percentage elongation of copper up to temperatures of 400 degrees Fahrenheit, or more. It is, then, probable that the many fractures of copper steam pipes which have been recorded since the introduction of the triple-expansion engine are to be attributed to the fact that designers, in thickening the walls of their

pipes in order to withstand the greater pressures, failed to note that the extra stiffness accompanying this increase of strength required to be compensated for by augmented curvature in the line of piping. Amongst the failures of such pipes which have been investigated by the Board of Trade, by far the largest number appear to have arisen from an oversight of this nature. Once this fact has been recognized, there is little excuse for future accidents of a like nature; and, in view of the exceedingly fatal results which almost certainly follow, engineers neglecting to provide their pipes with such flexibility are undertaking a very grave responsibility.

So far, the objections to the use of copper are met easily enough, but the accident to the steam pipe of the *Prodano* raises questions of a totally different nature. This boat was built at Blyth, in 1890, and was engined by the North-Eastern Marine Engineering Company. Her steam pipes were examined externally in 1890 by Mr. Walliker, Lloyd's senior surveyor at Cardiff, who detected nothing wrong. Nevertheless, nine months later, one of these pipes burst at sea, killing two engineers and two firemen. At the Board of Trade inquiry subsequently held, the Court came to the conclusion that the explosion was due to the brazing being originally defective, an opinion which was not thought to be justified by the very experienced engineers who direct the technical department of Lloyd's Registry, and consequently caused them to seek the aid of Professor Arnold in endeavoring to definitely determine whether, as was their contention, brazing originally sound had deteriorated with length of years and service.

That the brazing was sound at the outset seemed to be settled by the fact that the burst pipe had originally been made in a straight length, and afterwards bent, whilst cold, to a sharp curve; but how or why subsequent deterioration should have occurred was by no means obvious. To clear this up, portions of the broken pipe and its fellow were sent to Professor Arnold, together with samples of a brown incrustation scraped from the interior of the latter, some of the cylinder oil used, a sample of "Zynhara," an anti-corrosive fluid used in the *Prodano's* boilers,

portions of the main steam pipe from another vessel, specimens of the brazing solder used, and of Muntz metal, both in the newly-cast state and as deteriorated by the action of bilge water. Micrographic examination of the various metallic specimens were made by Professor Arnold.

Starting with the sample of Muntz metal, it was found that in the case of the specimens which had been corroded by bilge water, large areas presented an appearance totally different from that exhibited by specimens of the new metal. On examining in the same way the brazed seams of the *Prodano's* pipes, a similar change was found to have occurred in a large proportion of the solder. Whilst portions of this still retained the original internal structure of the brazing, large areas showed up as a finely-granulated, coppery-looking mass.

Unfortunately, a sufficiency of this solder could not be obtained from the pipes of the *Prodano* for an accurate analysis of the original and altered composition of the solder to be ascertained; but, as it chanced, the steam pipes of another steamer were found by Mr. Walliker to resemble those of the *Prodano* at his last examination of that vessel. Portions of these pipes were also sent to Professor Arnold, and a similar alteration in the solder established, whilst the amount of solder now available permitted of its being accurately analyzed. When the pipe was new, this solder contained probably about 62 per cent. of copper, an amount which was greater than it contained when newly cast, since a certain proportion of the zinc always volatilizes during the operation of brazing. In its deteriorated state this solder contained but 18 per cent. of zinc, and its porous condition is shown by the fact that its specific gravity had fallen from 8.24 to 7.45.

Moreover, Professor Arnold discovered that even the remaining zinc no longer existed in the metallic form, but was completely oxidized. This oxidation, Professor Arnold thinks, was brought about by the action of fatty acids arising from the decomposition of the lubricating oils used in the cylinder by the high-pressure steam. These acids found their way from the cylinder to the condenser, thence to the boiler, and finally into the steam pipe, with the results just set forth. As against this, it has to be

noted that Professor Arnold failed to effect saponification of a mineral oil stated to be similar to that said to be used on board the *Prodano*, even after exposure to a brisk current of steam for an hour, and this point seems in need of further elucidation. If the mineral oils now used as cylinder lubricants can be decomposed in this way and bring about such serious corrosion, quite new regulations as to the use of brazed seams will be required; but it is quite possible that through accident or inadvertence, vegetable or animal oils may have been employed on the *Prodano*.

With a view to avoiding such accidents in the future, the assessors at the Board of Trade inquiry made several recommendations, the most practical of which is the proposal to do away with copper pipes altogether and substitute iron or steel ones. The other suggestions made seem much less to the point, and in particular the court appear to have attached exaggerated weight to the value of hydraulic tests. In fact, they recommend that all copper steam pipes over $3\frac{1}{2}$ inches in diameter should be tested every four years, under an hydraulic pressure, straining the metal up to $2\frac{1}{2}$ tons per square inch. Such tests are very often fallacious, and seem particularly so in the case of a pipe having a brazed seam. Were deterioration general, some valuable information might, perhaps, be obtained by observing the deformation of the pipe under pressure, but, the wasting away being quite local, the total deformations will naturally be but little affected. In fact, the matter is very much on all fours with the dead-load test of a bridge, where a weak bar may be dangerously overstrained without practically affecting the deflection of the bridge under test, or otherwise giving evidence of its unfitness for its work. Indeed, a piece of the *Prodano's* pipe, in which the brazing was afterwards found by Professor Arnold to be seriously corroded, only burst when afterwards tested on the pressure reaching 890 pounds per square inch, or nearly six times the working pressure, which, in itself, shows the inconclusiveness of the proposed hydraulic test.

Where copper pipes are used the court recommended that they should be wrapped with wire. That safety can be secured in this way is not open to doubt, since our heavy guns, as now

manufactured, owe the major portion of their strength to wire wrapping; but theory shows, and experiment has confirmed it, that to be effective such wrapping should be close. Lloyd's committee do not appear favorable to this method of reinforcing pipes, though in their report on the *Prodano* explosion they have refrained from formulating their objections in detail, simply stating that in most of the explosions recorded little or no benefit would have been gained had the pipes been wire-wound. So far as these failures have been due to insufficient provision for expansion, this view is probably well based; but the seriousness of the *Prodano* accident would certainly have been greatly diminished had the steam pipes been thus strengthened.

The Board of Trade Assessors further recommended the thorough examination and inspection of steam pipes at comparatively short intervals; and such inspections, where the conditions are at all favorable, certainly give much more information as to the safety of a structure than any hydraulic test. Unfortunately, however, the deterioration of the brazing, which was responsible for the *Prodano* disaster, occurs mainly at the interior of the pipe, the outside of the seam being comparatively little affected; this being more especially the case when the pipe is covered with lagging, which prevents the access of corrosive agents to the outer side of the joint. The difficulties of satisfactorily inspecting the interior of a main steam pipe are obvious, and in most cases would seem insuperable.

For stationary engines we many years ago used wrought-iron riveted main steam pipes, which have given great satisfaction; but, as already pointed out, there is usually in these cases ample space to get in a long pipe with a couple of right-angle bends, which easily provide the expansion. On board ship space is more cramped, and hence expansion joints must be adopted if steel or iron pipes are used. For experimental work, the very ingenious flexible metallic tubing introduced some years since has been proved a great convenience, enabling an engine to be erected on the testing bed with an expenditure of a minimum of time and trouble. Such tubing has been used in this way for quite high steam pressures, though it is no doubt possible it might prove less satisfactory

as a permanent fixture. There is, however, no fear of its being injured by expansion strains, which appear responsible for most of the steam-pipe accidents.

CHICAGO SHIP BUILDING CO.'S MACHINE SHOP.

The shop was designed by the Wellman-Seaver Engineering Co. of Cleveland, to the ideas of Manager W. I. Babcock of the ship yard, and working drawings were furnished, from which the ship yard management built the shop complete with its own force.

The shop consists of a central bay 60 feet wide and 60 feet high under the trusses of the roof, giving 53 feet from floor to crane rail, and two side bays 30 feet each. The columns supporting the roof and crane girders are 40-foot centers. The upper roof is slate and the side roofs are ¼-inch ribbed glass set in metallic frames. But three bents, or 120 feet in length, of the shop have been built, but the shop can be extended as the necessity arises to 450 feet in length, or additional bays, on the saw-tooth roof principle, can be added on either side, the iron work being designed for that purpose. The crane girder and columns are built to carry two 25-ton cranes working together, though but one has been installed, and as yet only the brackets provided for the lower girder for a light auxiliary crane.

The shop has no galleries. Its distinguishing features are the amount of unobstructed floor room (there being but four columns in a space 120 feet square) and the great amount of light. In these features it has probably never been equaled. The inside and all the tools are painted white, and on a dark day, from the number of cross reflections, it is actually lighter than it is outside.

The heating arrangement consists of a hot-air system with steam coil and fan, installed by the American Blower Co. of Detroit. It is thoroughly satisfactory in every respect, the fan being run very slowly in the coldest weather. The 25-ton electric crane was made by the Brown Hoisting & Conveying Machine Co. of Cleveland. In each side bay is a 5-ton hand crane.

The tools include a floor boring, drilling and milling machine

of special design, which is the largest tool of the kind in the West and one of the largest in the country. The horizontal travel is 16 feet, vertical 10 feet, and the spindle feeds in 6 feet, the bed plate being 20 feet square with an 8-foot circular table having 3-inch power cross feed. The big lathe is 72 inches swing by 25 feet between centers, and there are planers, slotters, radial drill, shapers, small lathes, etc., as usual. The small tools in each bay are served from one line of shafting driven by a motor at the end. The floor boring machine and big lathe have separate motors attached. This leaves the main floor of the shop entirely clear of belts, etc. All motors used are supplied by the Elwell-Parker Electric Co. of Cleveland, who also furnished the generator which runs them and the motors for the rest of the plant, which was changed to motor drive in all departments on the central power-house system when this shop was finished.—"Marine Review."

TENSILE TESTS AT HIGH TEMPERATURES.

Some interesting experiments have been made at the Royal Technical Institute at Charlottenberg on the effect of heat on the physical properties of certain metals. The materials tested included iron, open-hearth steel, copper, samples of delta metal, both cast and forged; and finally manganese bronze containing different proportions of manganese. To secure uniformity in the results the specimens for a series of experiments on any particular metal or alloy were cut from a single bar. The tensile strength of each material was ascertained at ordinary temperatures, and at those of 212 degrees Fahrenheit, 392 degrees Fahrenheit, 572 degrees Fahrenheit, and 752 degrees Fahrenheit, three tests being made at each temperature with each of the metals save the manganese bronzes containing more than 3.2 per cent. of manganese. With these latter only two specimens were broken at each temperature.

For temperatures up to 572 degrees Fahrenheit the test bars were heated in vapor jackets, which surrounded the specimen as it stood in the machine. For the temperature of 212 degrees Fahrenheit the vapor used was, of course, that of water, whilst for the temperature of 392 degrees Fahrenheit naphthalene vapor

was employed, and for that of 572 degrees Fahrenheit naphthylamine vapor. In the case of the temperature of 752 degrees Fahrenheit the specimens were immersed in a bath of an alloy of lead and tin. In each case the actual temperature of the bath, whether liquid or vaporous, was determined by means of a thermometer. The extensions of the bar under test were measured by a mirror micrometer.

The conclusions reached by the experimenters were that in the case of iron it is necessary to attain a temperature of 572 degrees Fahrenheit before it can be forged, etc., without injury to its properties, whilst with an open-hearth steel a still higher temperature is necessary. Cast delta metal, it was found, should wrought at the same temperature, but in the case of the forged metal, a higher temperature is demanded. The manganese bronzes appeared to maintain their strength remarkably well up to a temperature of 482 degrees Fahrenheit, and this alloy can certainly be taken as having practically the same resistance at 392 degrees Fahrenheit as at ordinary temperatures. The alloy giving on the whole the best showing was found to be that containing between 5 and 6 per cent. of manganese, and is the one recommended for use in practical engineering work.

TERMS OF STEAM ENGINE EFFICIENCY.

A committee of the British Institute of Civil Engineers, appointed a year or more ago, says "Science," have reported the following recommendations on steam engine efficiency, and they have been adopted by the council:

(1) That the statement of the economy of a steam engine in terms of pounds of feed water per indicated horse power per hour is undesirable.

(2) That for all purposes except those of a scientific nature it is desirable to state the economy of a steam engine in terms of the thermal units required per indicated horse power (or per minute), and, if possible, the thermal units required for brake horse power should be given also.

(3) That for scientific purposes the thermal units that would

be required by a perfect steam engine, working under the same conditions as the actual engine, should also be stated.

The proposed method of statement is applicable to engines using superheated steam as well as those using saturated steam and the objection to the use of pounds of feed water, which contains more or less thermal units according to conditions, is obviated, while there is no more practical difficulty in obtaining the thermal units per indicated horse power per hour than there is in arriving at the pounds of feed water.

For scientific purposes the difference in the thermal units per indicated horse power required by the perfect steam engine and by the actual engine shows the loss due to imperfections in the actual engine.

A further great advantage of the proposal is that the ambiguous term "efficiency" is not required.

THE THORNYCROFT BOILER FEED REGULATOR.

At one time the irregular feeding of a group of water-tube boilers, supplied with water from a single feed pump, was one of the chief objections raised against the use of that form of steam generator on shipboard. Had it not been for this difficulty, there is little doubt that water-tube boilers would have been tried on board the torpedo ram *Polyphemus*, when her original locomotive-type boilers failed so disastrously. Had such a step been taken it might have modified the subsequent history of marine engineering, although this possibility would have been affected by the fact that the water-tube boiler of nineteen years ago was far from the more perfect apparatus it has since become. Messrs. J. I. Thornycroft & Co., of Chiswick, as one of the pioneer firms in the field of express boiler invention, were also amongst the first to see the need of a feed-regulating arrangement, and we now illustrate the most modern form of the device they introduced for the purpose.

Referring to the illustrations, Fig. 1 is a part sectional elevation through the upper chamber or steam drum of a Thornycroft boiler, the feed-controlling device being shown. Fig. 2 is an end elevation half in section. Fig. 3 is a plan; Figs. 4, 5 and 6, sec-

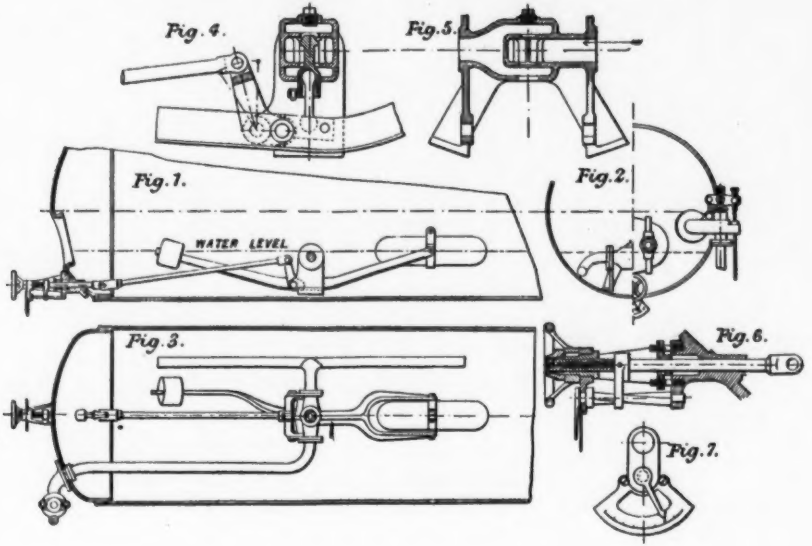


Fig. 4.
Fig. 5.
Fig. 1.
WATER LEVEL
Fig. 2.
Fig. 3.
Fig. 6.
Fig. 7.

tional details on to a larger scale; and Fig. 7, the indicating device. It will be seen that the principle involved is similar to that of an ordinary ballcock. There is a solid-drawn steel float, which is held in the forked end of a lever, and is balanced by a counterweight as shown. As the water level rises and falls, and the float follows it, a movement of the lever is obtained by which a valve, controlling the admission of feed water, is operated. The valve, shown in longitudinal section in Fig. 5, and cross-section in Fig. 4, is placed inside the boiler, and therefore the actuating mechanism is not retarded by having to pass through stuffing boxes.

A novel feature of considerable value is the controlling gear, which enables the float to be adjusted so that it will maintain the water level at any determined height within the range of the apparatus. The average amount of valve opening to admit sufficient feed water actually varies with different rates of steaming, and it is in order to prevent too great a range between the height of water level when light duty is required from the boiler, and that at full power, that the controlling gear is fitted. In order to effect this adjustment the vertical position of the fulcrum of the lever is altered. The latter is mounted on one arm of a bell-crank, the position of which can be adjusted by a rod which passes through a stuffing box in front of the boiler as shown. There is a screwed end to the rod and this engages in a screwed hub of a handwheel. It will be seen that by turning the handwheel the feed valve is opened or closed, the float, of course, remaining stationary, and, therefore, with a given water level there will be greater or less opening of the valve. Naturally, when a small supply of feed is needed the opening is smaller than when the boiler is being worked full power.

The gear is designed to enable several boilers to be fed by a pump common to all, without fear of the fluctuation in water level which might otherwise be caused by a little extra steam pressure or a slight difference in the adjustment of check valve. The absence of any spring device or of any of the automatic movements being transmitted through stuffing boxes, as already mentioned, or of nicely-adjusted sliding parts, are features of

great value. We are informed that in actual working this automatic feed regulator has proved eminently satisfactory. In proof of this it is pointed out that boilers giving steam for over 450,000 indicated horse power have had the gear applied to them. Our own observation on trials of vessels fitted with the device has been that no trouble has occurred through irregularity of boiler feeding.

In the experimental running on land the apparatus has worked successfully with an excess of pressure in the feed pipe of no more than 10 pounds to the square inch. With this low pressure, however, too large an apparatus would be required in such vessels as destroyers, and for a given variation of the rate of feed the motion of the valve, and consequently of the float and water level, would be greater; hence more frequent adjustment would be required when the rate of steaming was altered than is the case with higher feed pressures. On the other hand, too great an excess of pressure might lead to cutting of the valve or seatings. There is no difficulty, however, in working with the moderate difference that is sufficient for the purpose. The apparatus can be applied for regulating the feed of boilers of various descriptions, and Messrs. Thornycroft have executed orders for sets to suit water-tube boilers of other types than their own, locomotive-marine boilers, and return-tube boilers of the largest type in the Royal Navy, as well as Cornish and other descriptions of land boilers.

A point upon which stress is laid is that a good feed pump should be used; this should be capable of maintaining a steady excess of pressure in the feed pipes of not less than 15 pounds, and preferably 30 pounds to 40 pounds to the square inch should be used. If this is provided, it is said that a satisfactory result is certain to be secured. Messrs. J. I. Thornycroft & Co. find that with these pressures the maximum range of water level between the highest and lowest powers of these destroyers is so small that, when once properly adjusted, it is unnecessary to again touch the controlling gear.

Other advantages claimed are that, owing to the feed being continuous, the feed pipes inside the boiler can often be made smaller. The valve is never quite closed while the boiler is at

work. When not steaming the donkey should be shut off. The tendency to prime is reduced by using the gear. Priming often leads to false water in the gauge glass, and this results in an attempt to control the supply in a manner that may result in serious trouble. The automatic device naturally is not led astray by "false water." The apparatus, therefore, admits more water just when it is wanted and not when it merely appears to be wanted.—"Engineering."

THE GREAT DRY DOCK AT GLASGOW.

Early in May, Glasgow's new graving dock will be actually used for the first time, and the occasion will be marked by becoming ceremony. The caisson at the entrance and the dividing gates about the middle of the dock have now been made tight, and the piling and banking at the entrance has been all but cleared away. For some time past the dock has been practically finished and has only been waiting the erection of the pumping machinery and other mechanical accessories to make it thoroughly complete. The pumping installation here, it is understood, is the largest as yet laid down in connection with docks anywhere.

The body of the dock is 880 feet in length by 115 feet wide at top, and 81 feet 8 inches at bottom, and when filled to a depth of 28½ feet, as will be the case with spring tides, the total capacity will be about 2,202,000 cubic feet, corresponding to about 13,762,500 gallons, or about 61,500 tons of water. The emptying of this immense body of water will be accomplished in two hours. This duty, however, the plant may not often be called upon to perform, the dock being divided in its length by the gates already referred to. These will lock a ship 420 feet long into the inner compartment, leaving the outer free for the use of a 460-foot ship, which, of course, can be locked in or out by the ordinary caisson gates at the entrance, independently of the inner compartment and without disturbing the ship there. Up to the present, the Glasgow dock is the longest in existence, though apparently, it will not be long permitted to hold that distinction, as the projected dock improvement scheme at Liverpool includes a graving dock 900 feet in length, or 20 feet longer than that at Glasgow.—"Marine Engineer."

NEW DRY DOCK AT NEWPORT NEWS.

Work was commenced in the latter part of March on the new dry dock on the property of the Newport News Shipbuilding & Dry Dock Company, at Newport News, Va. Engineers are preparing the working plans, and as soon as these are completed the work of excavating for the mammoth basin will begin. The dock will be the largest in the United States. It will be 750 feet long and 160 feet wide at the top. This will enable the basin to accommodate two first-class battleships at one time. It is estimated that it will require two years to complete the work. The huge basin will cost about $1,000,000.

BRIQUETTES AS FUEL FOR TRIAL TRIPS.

Speaking at the New York meeting of the American Society of Naval Architects and Marine Engineers, Mr. A. F. Yarrow stated that for torpedo-boat fuel the briquettes used by the French Government possessed great advantages. These briquettes are made from Welsh coal carefully selected and washed. In trials of long duration there is, consequently, no clinkering; in fact, Mr. Yarrow went on to state, that when he had difficulty in getting a trial through with Welsh coal, he sent over for French briquettes, and then very often had no further difficulty.

BILGE KEELS ON MERCHANT STEAMERS.

Bilge keels have recently been fitted to the Cunard Line twin-screw steamers *Campania* and *Lucania*, and have reduced the rolling of these vessels considerably. The new White Star Liner *Cymric* has had bilge keels fitted during construction, and is the pioneer vessel of that company's fleet in that respect.

REVERSING IN STEAM TURBINES.

Mr. Parsons, of steam turbine fame, has succeeded in producing a turbine of the general type which is known by his name, which is capable of running in the reverse direction. At the time that the performance of the *Turbinia* startled the marine

world, it was pointed out that such a boat would be useless for torpedo warfare because she was unable to reverse her engines. To remedy the defect, Mr. Parsons first proposed to install a separate motor for running astern—an obviously uneconomical arrangement. It is now stated that by using a system of "butterfly" reversing steam valves a motor is constructed in which the steam may be made to flow through the blades of the turbine in either direction—the whole horse power of the engine being thus available for going astern.

In a recent letter, the Parson's Marine Steam Turbine Co., Limited, Newcastle-on-Tyne, state that the *Turbinia* easily steams 7 knots astern and the company are guaranteeing 15½ knots astern in the case of some of the torpedo-boat destroyers. Small separate astern turbines are used for reversing one or more of the screw shafts for going astern, and the time required for reversal of the engines from full speed astern is much less with turbines than with ordinary engines.

CARE OF WATER-TUBE BOILERS IN THE BRITISH NAVY.

Since the introduction into the naval service of water-tube boilers, naval engineers have experienced considerable difficulty in consequence of there being no means of readily detecting the presence of salt water in the feed circuit. Experiments have been conducted by the Admiralty chemist, assisted by engineer experts; and as a result of these experiments the Lords of the Admiralty have decided to supply very sensitive hydrometers and nitrate of silver solution to all ships fitted with water-tube boilers. The hydrometers will readily detect any rise of density; while the nitrate of silver, which will be used for testing the water produced by the evaporators or formed in the main condensers when steaming, will show whether the water is quite fresh or not, and also if the fittings are in proper order.

THE BRITISH NAVAL ESTIMATES.

The naval estimates for the financial year just commencing have been published, and according to them the sum of £25,550,000 is

to be spent upon the Navy during the next twelve months. The estimates alone are for a net total of £23,878,400, a net increase of £1,440,400 over those of last year, which included a supplementary estimate of £500,000. The increase in the number of officers, men and boys proposed has necessitated an increase in nearly every vote connected with the personnel. The works vote for the coming year does not differ materially from that of the present year. The shipbuilding vote shows an increase of £1,571,000 over the original estimate of 1897–98, but £1,400,000 of this sum represents money unexpended during the past financial year, chiefly owing to the dispute in the engineering trade.

The number of officers, seamen, etc., voted for 1897–98 was 100,050, but this year these numbers will be brought up to 106,390, the increase being made up of 200 officers, 2,400 seamen, 284 engine-room artificers, 1,700 stokers, 1,000 marines, 300 boys and 456 artisans and miscellaneous ratings. Of the 200 officers, half of them will be engineers, including 50 warrant officers, to be called artificer engineers.

A committee has been appointed to investigate the general question of recruiting for the Navy, the report of which is now under consideration. With the view of retaining as many artificers as possible, after they have completed time for pension, an order in Council has been obtained extending to engine-room ratings the privilege of sixpence a day "extension pay," allowed in other cases of men who remain in the service after completing time for pension.

Coming to the marines, the total number of recruits raised during the year was 2,665. Very few of these were over twenty years of age. The emoluments, too, of Royal Marine officers afloat has been improved somewhat, senior officers receiving a flag allowance when employed in ships carrying the flags or broad pennants of flag officers or commodores.

As regards the Royal Naval Reserve, provision is to be made to increase the list of executive officers by 100. Instruction has been given to a small experimental class of engineer officers of the Royal Naval Reserve in the Portsmouth Steam Reserve, between October 1st and December 31st last, in order that they

may acquire a knowledge of the working of the engines and boilers at present used in the ships of the Royal Navy.

The scheme of creating a warrant rank in the engineering branch of the Navy, which was foreshadowed in the House of Commons in the early part of the last session, was recently promulgated. The circular states that the Lords of the Admiralty, in order to insure the promotion of deserving engine-room artifices of long and meritorious service, and to provide for the future requirements of the fleet, have approved of the introduction of a new class of engineer warrant officer, to be known as an artificer engineer. Men to be promoted to this rank must be selected from the engine-room artificers, or the chiefs of that rating, who have had at least ten years' confirmed service, who are not less than thirty-five years of age, and who have passed the prescribed examination.

TRAVELING GANTRY AT HARLAND & WOLFF'S.

The largest gantry in the world has been erected at the shipbuilding yard of Messrs. Harland & Wolff to facilitate the building of such immense vessels as the White Star *Oceanic*, now in course of construction. The clear height from the rail level to the under side of the cross girders is 98 feet, and the clear space between the vertical legs is 95 feet. These dimensions will not only admit the largest vessel now building, but they provide for the future requirements for a long period.

The object of the gantry is to facilitate the lifting of plates and sections into position, and also to support riveting machines when at work, many of them being exceedingly heavy. The lifting is done mainly by four jib cranes situated at the four corners of the structure. Each of them is capable of lifting 4 tons through a height of 80 feet, at a rake of 40 feet. It swings through an angle of 180 degrees, and can thus cover a space of about 80 feet at each side of the center line of the ship. The hydraulic cylinders and valves for each crane are placed on the corresponding leg of the gantry near the ground, steel wire ropes passing over

guide pulleys controlling the several motions for lifting, racking and slewing.

There are three hydraulic traveling cranes on the cross girders, two being on the upper boom and one on the lower, to enable them to work very closely together. These cranes are controlled by hand from the level at which the machines are worked. They are maneuvered by means of chains depending from sprocket wheels, and the great length of these chains is found to be no disadvantage, but rather the contrary. These cranes are generally used for supporting portable riveting machines, which are carried upon hydraulic lifts suspended from the traveling carriages of the cranes by chains of flat steel links, so arranged that the links can easily be put in or taken out according to the height at which the machines are being worked.

The entire gantry runs on double rails laid down on both sides of the berth. These rails consist on each side of a pair of strong steel H-section bars, with flat steel bars riveted upon the upper surface. The two H-sections are braced together by cross pieces, and are bedded upon continuous blocks of concrete carried on piles; the total length of the rails is about 650 feet, and the double rails are 100 feet apart, center to center. As the berth is on an incline of gradually increasing declivity, Messrs. Harland & Wolff suggested laying the rail path to a vertical curve of very large radius. This avoids the use of high embankments or deep cuttings. It, of course, causes the gantry to be inclined slightly out of the vertical to one side at one end of its travel, and slightly to the other side at the opposite end; but this variation is of no practical importance, and does not interfere with the proper working of the cranes.

The gantry is propelled along the double rails by two hydraulic engines, actuating worm gear upon the traveling wheels. These engines are of the three-cylinder, single-acting type, with externally hemp-packed rams, all parts being easily accessible. There is one engine at each side, but these are connected by vertical and horizontal shafts, carried up the legs and along the main girders. These shafts insure that the two sides of the gantry shall advance

equally, and work very satisfactorily. As each side has its own engine, there is very little power transmitted through the shafts.

The gantry is constructed of steel, and is securely braced together. At the four corners, the girders are plated to increase the stiffness. Hydraulic pressure and return piping is carried up each of the four legs and across the top of the gantry, suitable branch pieces and hydrants being provided where necessary for use, coupling to riveting machines in whatever positions they may be required, and pressure is taken from an hydraulic main running along the end of the berth, the connection being made by large flexible armored hose. The exhaust water is also returned to the pump station through suitable mains, so that the same water is used over and over again.

Rivet-heating furnaces have been placed by Messrs. Harland & Wolff at different levels on each side of the gantry, in such positions as will enable the machines to be readily supplied with rivets at any part of the ship. Staging and ladders are fitted to enable all parts of the gantry and machinery to be easily accessible for examination.

When the description was written, the riveting machines were being used for riveting up the double bottom of the ship, but, as the construction of the ship advances, links will be taken out of the carrying chain, and the machines brought to bear upon the decks and other parts of the ship. The riveting machines are of the well-known Fielding type, which was originally designed for riveting up the double bottoms of ships, its special advantage being great lateral rigidity when working with very long gaps.

In addition to these machines others of a different type have also been supplied. These are of the direct-acting type, and have a gap of 7 feet, and are capable of dealing effectively with $1\frac{1}{4}$-inch rivets. The Fielding type machines above referred to have a gap of 6 feet, and are of the same power.

Messrs. Fielding & Platt have also in construction, for work in conjunction with the gantry, a powerful hydraulic portable punch, capable of punching $1\frac{1}{4}$-inch holes in plates $1\frac{1}{8}$ inches thick. It will be used for punching the plates in the top strakes of the ship, the plates being fixed against others which have been pre-

viously drilled or punched, the portable machine using the latter as a template, thus insuring exact fairing of holes.

The general design for this gantry was suggested by Messrs. Harland & Wolff. The entire contract for the structure and machinery was placed in the hands of Messrs. Felding & Platt, Limited, of Gloucester, who are responsible for the details and for its efficiency; the building of the structure was sublet by them to Messrs. Arrol's Bridge and Roofing Company, Germiston Works, Glasgow, who have performed their portion of the work with their usual ability.

The gantry has been found to be an entire success, and no accident to life or limb has been met with, which is highly satisfactory considering the magnitude of the job, and the difficulties to be encountered when working at such a height, and often in heavy weather.

SHIPS.

UNITED STATES.

Kearsarge and **Kentucky.**—The launching of these twin battleships was successfully carried out at the Newport News Shipbuilding and Dry Dock Company's yard on March 24. They have already been described in Vols. VII and VIII of the JOURNAL.

Maine.—The court of inquiry which investigated the destruction of this vessel, which occurred in the harbor of Havana on February 15, reported that it was caused by an external explosion. The report has been printed as a public document and has been reprinted in many papers. Our space does not permit of a reproduction of the report, but it may be said that the investigation was carried out with the greatest care and thoroughness, and a careful study of the report leaves no room for doubt that the *Maine* was destroyed by the explosion of a powerful submarine mine. The court did not locate the authors of the crime, but as powerful mines can not be laid in harbors by individuals, the logical conclusion as to responsibility is inevitable.

New Orleans.—In March of this year, the Navy Department purchased from Sir W. G. Armstrong, Whitworth & Co. the cruiser *Amazonas*, built for the Brazilian Navy, and her name was changed to *New Orleans*. A sister vessel, the *Abrouil*, renamed *Albany*, was also purchased but she was not sufficiently advanced for delivery before the outbreak of the war with Spain. The *New Orleans* is, of course, built of steel, and has the advantage of being sheathed with teak and coppered.

The *New Orleans* is a twin-screw protected cruiser of 3,450 tons displacement. She was built by Sir W. G. Armstrong, Whitworth & Co., at Elswick, Newcastle-on-Tyne, for the Brazilian Government, and was launched December 4, 1896. The engines and boilers were built by Messrs. Humphreys, Tennant & Co., Deptford, London. The ship was turned over to Lieutenant J.

C. Colwell (naval attaché to U. S. Embassy, London), at Gravesend, England, on March 18, 1898. Lieutenant Commander A. P. Nazro and a detachment of officers and men from the U. S. S. *San Francisco* took possession on the afternoon of the same day.

The protective deck extends the whole length of the ship. It is 1¼ inches thick on the flat part and 3½ inches thick on the sloping sides. The battle hatches over the engine rooms are solid.

Length over all, feet and inches	351–6
Length load water line, feet and inches	343–2
Breadth, feet and inches	43–9
Draft, forward, feet and inches	16–9
Draft, aft, feet and inches	17–3
Draft, mean, feet and inches	17–0
Displacement, tons	3,450
Speed, knots	21
I.H.P. (estimated)	7,500
Coal capacity, tons	800

The armament consists of six 6-inch quick-firing guns; four 4.7-inch quick-firing guns; ten 6-pounders; four 3-pounders; four Maxim automatic guns; three 37-millimeter 5-barrel machine guns, and two 12-pounder field guns. The front part of the shields protecting the 6-inch and 4.7-inch guns is 4 inches thick, the tops of these shields being about ½ inch and the sides about 1⅛ inches thick. The thickness of the conning tower is also about 4 inches.

There are three torpedo tubes for Whitehead torpedoes: one in the bow and one on each side forward. All are above water.

The engines are three-cylinder, vertical, inverted, triple-expansion, with piston valve to the high, and double ported slide valves to the intermediate and low-pressure cylinders.

Diameter H.P. cylinder, inches	31
Diameter I.P. cylinder, inches	46
Diameter L.P. cylinder, inches	70
Stroke, inches	30
Diameter H.P. piston valve, inches	18¾
Diameter piston rods, inches	6½
Diameter air pump water cylinder, inches	14

There is one surface condenser to each engine. Exhaust steam enters at one end and passes through the tubes to the air pump suction end. The circulating water enters at the bottom, and is guided by diaphragms so as to give good circulation around all the tubes, the discharge being at the top.

Water is supplied to each condenser by a centrifugal circulating pump driven by an engine having a steam cylinder of 9 inches diameter and 10 inches stroke.

The air pump is under the L.P. cylinder, and is driven by a rod connected direct to the L.P. piston.

There are four double ended, cylindrical, Scotch boilers, having three furnaces of the Purves type in each end. The safety valves are set at 155 pounds.

Mean diameter, feet and inches	12– 1
Length, feet and inches	17–10
Number of furnaces, each boiler	6
Diameter of furnaces, inches	36
Number of combustion chambers to each boiler	2
Grate area one boiler, square feet	120
Height smoke pipe above grate, feet	65

Closed fire room, forced draft.

There are two boiler compartments. There are two forced draft blowers in each fire room. There is a small donkey boiler above the protective deck.

The two forward boilers have a separate main steam pipe going to the starboard engine room, and the two after boilers have one going to the port engine room. There is a pipe connecting these two in the engine rooms having a pass-over valve in it.

There are two main and two auxiliary feed pumps. These are all Watson vertical, duplex pumps, 9 inches and 6 inches $\times$ 6 inches stroke. The auxiliary pumps draw from the main feed tank, the reserve feed tanks, the sea or the boilers. They discharge to the boilers or to the fire main. As originally fitted they did not have a boiler suction, nor was there a bottom blow to the boilers; and the only way of emptying a boiler was to drain it into the bilge. When the ship was at the New York

Navy Yard a bottom blow was fitted, and a connection run to the auxiliary feed pump manifold.

There is a small main feed tank between the engine and fire rooms. The double bottoms under fire rooms numbers 2 and 3 are used as reserve feed tanks. Their capacity is about 96 tons.

The propellers are of manganese bronze, and are three bladed. The pitch is variable within small limits, the mean pitch being 15 feet 9 inches. The diameter of the blades is 12 feet.

There is one main drain having suctions in each boiler compartment and in each engine room. The only pumps that have a suction from it are the two centrifugal circulating pumps.

There is a secondary drain running the length of the engine and boiler compartments. It has suctions from each engine and boiler compartment, and is connected by manifolds to several of the forward and after compartments and to the double bottoms. Originally the only pumps that had suctions from this drain were one Watson vertical, duplex pump in each engine room. These pumps also had a suction from the crank pit or bilge, and from the sea, and a discharge overboard or to the fire main. While at the New York Navy Yard one vertical duplex Blake pump was fitted in each engine room having the same suctions and discharges as the Watson pumps.

There is one distiller and one evaporator in the after part of each engine room. The distilling capacity is about 2,000 gallons per day. They were made by John Kirkaldy. They distil either to the ship's tanks or to the reserve feed tanks; or the evaporators may be put direct on the main condensers.

There are three dynamos, built by Sir W. G. Armstrong, Whitworth & Co., one above the engine room hatch, and one in the after part of each engine room. The output of each is 400 ampères at 80 volts pressure, and at a speed of 320 revolutions per minute. They are driven direct by vertical, inverted, compound engines.

There are four search lights, each taking a current of about 45 ampères. One is on the foremast, one on the main mast, and one on each side of the bridge.

There is one electrical ventilating fan and one steam ventilat-

ing fan forward on the berth deck for ventilating the forward magazines and store rooms. There is one steam ventilating fan in the starboard engine room and one electrical ventilating fan in the port engine room for ventilating the after magazines and store rooms.

There are electrical ammunition hoists for the 6-inch and the 4.7-inch guns. These have not proved very reliable so far, and provision has been made for hoisting all ammunition by hand.

[The JOURNAL is indebted to Assistant Engineer B. K. McMorris, U. S. Navy, for the foregoing description.]

Princeton.—The contract trial of this gunboat occurred in the Delaware River and Bay on May 11, 1898. The report of trial was not obtained in time for publication. We shall publish a description and account of the trial in the next issue of the JOURNAL.

Alabama.—Messrs. Cramp & Sons added another to the long list of successful launches at their yard when the *Alabama* was put in the water May 18. She was described in Vol. VIII of the JOURNAL.

MacKenzie.—The Charles Hillman Co., of Philadelphia, launched the torpedo boat *MacKenzie* on February 19. The contract trial is expected to take place the latter part of May.

McKee.—Torpedo boat No. 18, the *McKee*, was launched at the Columbian Iron Works, Baltimore, on March 5, 1898. Her trial was made on May 2, 1898, during the run from Baltimore to Navy Yard, Norfolk, where she was delivered to the Government, and work of preparing for sea immediately commenced.

The boat was run at full speed for two hours, but speed could not be accurately measured on account of the absence of stakes or boats. Speed, 19.82; average revolutions, 307; average steam pressure at engines, 211 pounds; average vacuum, 25.2 inches; average air pressure in fire rooms, 3 inches.

Talbot and **Gwin.**—The Herreshoff Co. launched these twin torpedo boats on November 14 and 15, 1897, respectively. A description of them and of their trials is given elsewhere in this number.

Morris.—A description of this torpedo boat is given elsewhere

in this number. She was launched at the Herreshoff Works on April 13, 1898.

Rodgers.—It will be remembered that during the trials of this torpedo boat on September 11, 1897, the port engine was completely wrecked by the breaking of the crank shaft. A new engine having been built, she was given a trial on her way from the works of the builders (the Columbian Iron Works) in Baltimore to Norfolk, Va., on March 19, 1898. Under the circumstances, accurate data could not be obtained, but as, on the previous trial, when the crank shaft carried away, the speed was over 24 knots, it is presumed that the speed is up to the contract requirement of 24.5 knots, the same as the speed of the *Foote* and *Winslow*.

Torpedo Boat No. 8, christened the *Rowan*, was launched from the yards of Moran Bros. Co., at Seattle, Wash., on the 8th of April. The act providing for this and two other torpedo boats was passed by Congress in the appropriations for the fiscal year ending June 30, 1895. The boat has a length over all of 175 feet 6 inches; extreme beam, 17 feet; normal draught, 5 feet 6 inches; displacement, about 185 tons; freeboard forward, 11 feet, and amidships and aft, 5 feet. The vessel has twin screws. The engines, placed in separate compartments, are of the vertical, inverted-cylinder, direct-acting, triple-expansion type, with four cylinders each; the low-pressure cylinders being divided into two to reduce the size of casting. The indicated horse power of the engines is estimated to be 3,200 at 395 revolutions per minute. The estimated speed is 26 knots per hour. The boilers, three in number, are of the Mosher patent tubular type. The armament consists of three 18-inch Whitehead torpedo tubes and four 1-pounder rapid-firing guns. The boat will be manned by four officers and twenty men. The normal coal supply is twelve tons and the total bunker capacity sixty tons, giving a steaming radius of 1,092 knots, at a speed of 13 knots per hour. The hull is built of steel throughout, the main portions below the water line being galvanized and divided into twenty-six watertight compartments, each fitted with a steam ejector for clearing of water. The coal is carried in wing bunkers outside of the

Old name.	Old class.	Length.	Breadth.	Depth.	Draught.	Displacement.	Propulsion.	H.P.
		ft. in.	*ft. in.*	*ft. in.*	*ft. in.*	*tons.*		
Abrouil	Protected cruiser	330	43 9	25	16 10	3,450	Twin screws	7
*Ægusa**	Steel yacht	264	31 6	20 6	...	1,230 T. Y. M.	Single screw	2
Atice	Steam lighter	.....	...	...	...	260.02 gross	.....	.
Alicia	Yacht	160	22	13	11	425	Single screw	.
Almy	"	155 6	24	14	11 6	434	" "	.
Amasonas	Protected cruiser	330	43 9	25	16 10	3,450	Twin screws	7
Armeria	Lighthouse tender	212 ft. over all	34	17	12 6	.....	" "	200
Atlas	Ocean tug	130	25 6	14 6	12 6	462	.....	.
Calumet	Rev. cut'r, 2d rate	94 6	20 6	10 3	8 8	123 R. T.	Single screw	.
Columbia	Yacht	180	23	14 3	12	630	" "	1
Corwin	Revenue cutter	145 6	23	...	11 5	213 registered	" "	.
Creole	Coast liner	375	44	32 6	...	6,000 loaded	" "	3
De Witt C. Ivins	Tug	97	21	11	8	156	.....	.
Diogenes	Gunboat	250	35	21 9	10	1,800	Twin screws	.
Edward Luckenbach	Ocean tug	88 6	21 6	10 6	9 3	227	Single screw	500
El Norte	Coast. freight st'r	380 6	48	23 11	22	6,000 to 8,000	" "	3
El Rio	" "	390 6	46 10	23 11	22	" "	" "	3
El Sol	" "	390 7	46 10	31 6	...	" "	" "	3
El Sud	" "	380	48	39 9	...	" "	" "	3
El Toro	Tug	90	19	10 9	9	187	" "	.
Grant	Revenue cutter	163	25	11.4	9 6	263 registered	Screw	.
Guthrie	Rev. cut'r, 3d rate	87	17	8 5	8 7	98 gross	Single screw	.
Hamilton	Rev. cut'r, 2d rate	144 ft. over all	23	11 10	9 7	250	" "	.
Hermione	Yacht	145	22 6	13	11	375	" "	1
Hudson	Rev. cut'r, 3d rate	96 6	18 4	9 2½	9	174	" "	.
Josephine	Yacht	225	25	14	14	800	" "	1
Lebanon	Collier	246	37 5	29 5	...	3,500 loaded	" "	1
Mangrove	Lighthouse tender	164 ft. over all, 159 ft. between perps.	30	11 10	8	392 gross	Twin screws	.
Manning	Rev. cut'r, 1st rate	205	32	17	10 10	900	Single screw	2
Maple	Lighthouse tender	164 ft. over all, 155 ft. between perps.	30	11 10	...	392.06 gross	Twin screws	650
Mayflower	Yacht	275	36 6	30 ft. to bg'e deck	17 2½	2,690	" "	4
Mayflower	Lighthouse tender	164	30	11 10	8	392.06 gross	" "	.
McCulloch	Rev. cut., comp'site	219	33 4	17 10	14	1,280	Single screw	2
Merrimac ††	Freighter	330	44	29	...	2,556 net	" "	.
Morrill ¶	Rev. cut'r, 2d rate	145 3	24	12 3	8 6	322	" "	.
Nanshan ¶	Emigrant and cargo steamship	285	39 1	24 ft. unloaded.	Light	3,400 deadweight	" "	.
Niagara	Passenger steamer	274	38	23	19 6	5,221	" "	1
Nitchero ‡	Dynamite cruiser	380	48	...	22	7,080	" "	4
P. H. Wise	Tug	84	19	9	8	155	" "	.
Paoli ††	"	125 5	26	14 8	...	330.71 gross	" "	600
Perry	Revenue cutter	165	25	11 2	...	282 gross	" "	.
R. W. Wilmot	Tug	136 8	28	17	...	.....	" "	2
Rush	Revenue cutter	175	26	15	12 6	300 gross	" "	.
Saturn	Salvage steamer	295 ft. over all	40	26 2	22 loaded	4,500 loaded	" "	1
Sovereign	Yacht	250 ft. 6 in. over all 210 ft. 6 in. bet. perps.	28 1	16 9	11 6	850	Twin screws	2
Sterling	Freighter	274	37	23 2	...	5,663 loaded	Single screw	.
St. Louis	Transatlantic liner	535.5	63	50.4	...	16,000	Twin screws	18
St. Paul	" "	535.5	63	50.4	...	16,000	" "	20
W. A. Luckenbach	Ocean tug	199 3	25	14 8	12	441	Single screw	.
Windom	Rev. cut'r, 1st rate	170 8	27	13 5	8 3	550	Twin screws	.
Winthrop	Ocean tug	125	26	15	14	571	Single screw	.
Woodbury	Rev. cut'r, 2d rate	146 6	28 6	11	11	330 gross	" "	.
Zafiro ¶	Cargo and pass. st'r	220	31 10	21 3	...	1,100 gross	" "	.
Unnamed	Torpedo b't, 1st cl.	152 (?)	...	...	...	140 (?)	.....	2
Unnamed	Torpedo boat	61	9	...	2 6	46	Single screw	.

*Bought in Italy. † These figures are for the Revenue Cutter Service. Corresponding ones for the Navy have

ELS RECENTLY ACQUIRED BY THE UNITED STATES NAVY BY PURCHASE, CHARTER OR TRANSFER. [Reprinted from

Horse power.	Speed.	Rig.	Where built.	Date of Build'g.	Hailing port.	Name of former owner.	New na
	knots						
7,500	20	2 military masts	Sir W. G. Armstrong, Whitworth & Co., Elswick, Newcastle-on-Tyne	1897	Brazilian Navy	Republic of Brazil	*Alba*
2,500	16.25	.....	Scott & Co., Greenock	1897	Palermo	Ignazio Florio	...
.....	...	.....	Rockyhill, Conn.	1882	Hartford, Conn.	.....	*Alic*
.....	18	Schooner	Harlan & Hollingsworth	1890	New York	H. M. Flagler	*Horn*
900	15 5	"	"	1890	"	F. Gallatin	*Eag*
7,500	20	2 military masts	Sir W. G. Armstrong, Whitworth & Co., Elswick, Newcastle-on-Tyne	1896	Brazilian Navy	Republic of Brazil	*New Or*
00 nominal	12	2-masted schooner	Camden, N. J.	1890	.....	United States	*Arme*
650	13	Schooner	Harlan & Hollingsworth	1896	New York	Standard Oil Co.	*Wompa*
500	13	Harbor tug	Buffalo, N. Y.	1894	U. S. R. C. S.	United States	*Calum*
1,800	18	Schooner	Wm. Cramp & Sons	1893	New York	J. Harvey Ladew	*Wasp*
350	10	"	Portland, Ore.	1876	U. S. R. C. S.	United States	*Corwi*
3,500	...	.....	Newport News S. B. & D. D. Co.	1896	New York	Cromwell Line	*Solac*
400	7	.....	Neafie & Levy	1897	"	Moran Towing Co.	*Nezinsc*
.....	16	Schooner	Thames Iron Works	1883	.....	Thames Iron Works, London, Eng.	*Topek*
00 nominal	11	"	John Dialogue	1896	New York	L. Luckenbach	*Tecums*
3,800	...	Steamship	Newport News S. B. & D. D. Co.	1892	"	Morgan Line	*Yanke*
3,600	17	"	" " " "	1892	"	" "	*Prair*
3,800	...	"	Wm. Cramp & Sons	1890	"	" "	*Yosemi*
3,600	...	"	Newport News S. B. & D. D. Co.	1892	"	" "	*Dixie*
250	10	"	" " " "	1891	"	" "	*Algonqu*
420	10	.....	Wilmington, Del.	1871	U. S. R. C. S.	United States	*Gran*
225	12	Harbor tug	Baltimore, Md.	1895	"	" "	*Guthr*
450	12	.....	Buffalo, N. Y.	1871	"	" "	*Hamilt*
1,000	14.5	Schooner	Fleming & Ferguson, Paisley, Scotland	1891	Boston	H. L. Pierce	*Hawk*
525	13.5	Harbor tug	Camden, N. J.	1893	U. S. R. C. S.	United States	*Hudson*
1,000	12.5	.....	Lewis Nixon	1896	Philadelphia	P. A. B. & G. D. Widener	*Vixe*
1,000	...	Schooner	Wm. Cramp & Sons	1894	"	Philadelphia & Reading R. R.	*Leban*
650	9	"	Lewis Nixon	...	United States	United States	*Mangro*
2,000	16	Brigantine	East Boston, Mass.	1897	U. S. R. C. S.	" "	*Mann*
50 nominal	9	2-masted schooner	S. L. Moore & Sons, Elizabeth, N. J.	1892	"	" "	*Mapl*
4,600	16.75	Brigantine	Clydebank, Scotland	1897	New York	Estate of Ogden Goelet	*Mayflow*
650	9	2-masted schooner	Bath Iron Works	1897	.....	United States	*Suwan*
2,300	17.23	3-masted schooner	Wm. Cramp & Sons	1897	U. S. R. C. S.	" "	*McCull*
280	...	.....	C. S. Swan & Hunter, Newcastle	1894	New York	T. Hogan & Sons	*Merrim*
500	12	Schooner	Camden, N. J.	1889	U. S. R. C. S.	United States	*Morri*
.....	14	"	Grangemouth Dock Yard Co.	1895	London	T. W. Richardson, London	*Nansh*
1,600	12	"	J. Roach & Son	1877	New York	New York & Cuba Mail S. S. Co.	*Niagar*
4,000	14	.....	Newport News S. B. & D. D. Co.	1893	Brazilian Navy	Republic of Brazil	*Buffa*
290	10	.....	Neafie & Levy	1892	New York	Moran Towing Co.	*Sioux*
00 nominal	...	Steamship	Chas. K. Hillman, Philadelphia	1895	Fall River, Mass.	Staples Coal Co.	...
400	11	Schooner	Buffalo, N. Y.	1884	U. S. R. C. S.	United States	*Perry*
2,000	...	"	F. W. Wheeler & Co., West Bay City	1897	New Orleans	W. G. Wilmot, New Orleans	*Potomac*
550	10.5	.....	Port Blakely, Wash.	1885	U. S. R. C. S.	United States	*Rush*
1,300	12.5	Schooner	Harlan & Hollingsworth	1890	Boston	Boston Towboat Co.	*Saturn*
2,800	17.85	.....	Hull, John N. Robbins; engines, W. & A. Fletcher	1896	New York	M. C. D. Borden	*Scorpio*
200	11	Schooner	Duncan & Co., Pt. Glasgow, Scotland	1881	"	C. A. Campbell & Co.	*Sterlin*
18,000	20.87	2-pole	Wm. Cramp & Sons	1895	"	International Navigation Co.	*St. Lou*
20,000	21.08	2-pole	" "	1895	"	" " "	*St. Pau*
750	12	Schooner	John Dialogue	1893	"	L. Luckenbach	*Uncas*
810	14	2 pole masts	Dubuque, Iowa	1896	U. S. R. C. S.	United States	*Windo*
.....	14	Schooner	Chas. K. Hillman & Co.	1896	Taunton	Staples Coal Co.	*Osceol*
500	11	"	Philadelphia	1864	U. S. R. C. S.	United States	*Woodbu*
200	12.5	.....	Hall, Russel & Co., Aberdeen	1884	Hong Kong	China & Manila S. S. Co.	...
2,500	25	.....	Schichau, Elbing, Germany	...	.....	.....	*Somer*
.....	17	.....	Yarrow	...	.....	Yarrow	*Manly*

ve not yet been determined. ¶ Reported bought by Commodore Dewey, on the Asiatic Station. ⁂ Originally the Morgan Liner *El Cid*

ENTLY ACQUIRED BY THE UNITED STATES NAVY BY PURCHASE, CHARTER OR TRANSFER. [Reprinted from "M

Speed.	Rig.	Where built.	Date of Build'g.	Hailing port.	Name of former owner.	New name.
knots						
20	2 military masts	Sir W. G. Armstrong, Whitworth & Co., Elswick, Newcastle-on-Tyne	1897	Brazilian Navy	Republic of Brazil	*Albany*
16.25	.....	Scott & Co., Greenock	1897	Palermo	Ignazio Florio	...
...	.....	Rockyhill, Conn.	1882	Hartford, Conn.	.....	*Alice*
18	Schooner	Harlan & Hollingsworth	1890	New York	H. M. Flagler	*Hornet*
15 5	"	" "	1890	"	F. Gallatin	*Eagle*
20	2 military masts	Sir W. G. Armstrong, Whitworth & Co., Elswick, Newcastle-on-Tyne	1896	Brazilian Navy	Republic of Brazil	*New Orleans*
12	2-masted schooner	Camden, N. J.	1890	.....	United States	*Armeria*
13	Schooner	Harlan & Hollingsworth	1896	New York	Standard Oil Co.	*Wompatuck*
13	Harbor tug	Buffalo, N. Y.	1894	U. S. R. C. S.	United States	*Calumet*
18	Schooner	Wm. Cramp & Sons	1893	New York	J. Harvey Ladew	*Wasp*
10	"	Portland, Ore.	1876	U. S. R. C. S.	United States	*Corwin*
...	.....	Newport News S. B. & D. D. Co.	1896	New York	Cromwell Line	*Solace*
7	.....	Neafie & Levy	1897	"	Moran Towing Co.	*Nezinscot*
16	Schooner	Thames Iron Works	1883	.....	Thames Iron Works, London, Eng.	*Topeka*
11	"	John Dialogue	1896	New York	L. Luckenbach	*Tecumseh*
...	Steamship	Newport News S. B. & D. D. Co.	1892	"	Morgan Line	*Yankee*
17	"	" " " "	1892	"	" "	*Prairie*
...	"	Wm. Cramp & Sons	1890	"	" "	*Yosemite*
...	"	Newport News S. B. & D. D. Co.	1892	"	" "	*Dixie*
10	"	" " " "	1891	"	" "	*Algonquin*
10	.....	Wilmington, Del.	1871	U. S. R. C. S.	United States	*Grant*
12	Harbor tug	Baltimore, Md.	1895	"	" "	*Guthrie*
12	.....	Buffalo, N. Y.	1871	"	" "	*Hamilton*
14.5	Schooner	Fleming & Ferguson, Paisley, Scotland	1891	Boston	H. L. Pierce	*Hawk*
13.5	Harbor tug	Camden, N. J.	1893	U. S. R. C. S.	United States	*Hudson*
12.5	.....	Lewis Nixon	1896	Philadelphia	P. A. B. & G. D. Widener	*Vixen*
...	Schooner	Wm. Cramp & Sons	1894	"	Philadelphia & Reading R. R.	*Lebanon*
9	"	Lewis Nixon	...	United States	United States	*Mangrove*
16	Brigantine	East Boston, Mass.	1897	U. S. R. C. S.	" "	*Manning*
9	2-masted schooner	S. L. Moore & Sons, Elizabeth, N. J.	1892	"	" "	*Maple*
16.75	Brigantine	Clydebank, Scotland	1897	New York	Estate of Ogden Goelet	*Mayflower*
9	2-masted schooner	Bath Iron Works	1897	.....	United States	*Suwanee*
17.23	3-masted schooner	Wm. Cramp & Sons	1897	U. S. R. C. S.	" "	*McCulloch*
...	.....	C. S. Swan & Hunter, Newcastle	1894	New York	T. Hogan & Sons	*Merrimac*
12	Schooner	Camden, N. J.	1889	U. S. R. C. S.	United States	*Morrill*
14	"	Grangemouth Dock Yard Co.	1895	London	T. W. Richardson, London	*Nanshan*
12	"	J. Roach & Son	1877	New York	New York & Cuba Mail S. S. Co.	*Niagara*
14	.....	Newport News S. B. & D. D. Co.	1893	Brazilian Navy	Republic of Brazil	*Buffalo*
10	.....	Neafie & Levy	1892	New York	Moran Towing Co.	*Sioux*
...	Steamship	Chas. K. Hillman, Philadelphia	1895	Fall River, Mass.	Staples Coal Co.	...
11	Schooner	Buffalo, N. Y.	1884	U. S. R. C. S.	United States	*Perry*
...	"	F. W. Wheeler & Co., West Bay City	1897	New Orleans	W. G. Wilmot, New Orleans	*Potomac*
10.5	.....	Port Blakely, Wash.	1885	U. S. R. C. S.	United States	*Rush*
12.5	Schooner	Harlan & Hollingsworth	1890	Boston	Boston Towboat Co.	*Saturn*
17.85	.....	Hull, John N. Robbins; engines, W. & A. Fletcher	1896	New York	M. C. D. Borden	*Scorpion*
11	Schooner	Duncan & Co., Pt. Glasgow, Scotland	1881	"	C. A. Campbell & Co.	*Sterling*
20.87	2-pole	Wm. Cramp & Sons	1895	"	International Navigation Co.	*St. Louis*
21.08	2-pole	" "	1895	"	" " "	*St. Paul*
12	Schooner	John Dialogue	1893	"	L. Luckenbach	*Uncas*
14	2 pole masts	Dubuque, Iowa	1896	U. S. R. C. S.	United States	*Windom*
14	Schooner	Chas. K. Hillman & Co.	1896	Taunton	Staples Coal Co.	*Osceola*
11	"	Philadelphia	1864	U. S. R. C. S.	United States	*Woodbury*
12.5	.....	Hall, Russel & Co., Aberdeen	1884	Hong Kong	China & Manila S. S. Co.	...
25	.....	Schichau, Elbing, Germany	...	.....	.....	*Somers*
17	.....	Yarrow	...	.....	Yarrow	*Manly*

een determined. ¶ Reported bought by Commodore Dewey, on the Asiatic Station. ‡ Originally the Morgan Liner *El Cid.*

e.	New class.	Commanding officer	Armament.	Complement. Officers	Men
	Protected cruiser	Not detailed	Six 6-in. r. f., four 4.7-in. r. f., ten 6-pdrs., four 1-pdrs., four Maxims, two field guns	Not in Commission	
	Despatch boat	.....	.....	.....	
	Supply boat	.....	.....	.....	
	Auxiliary gunboat	Lt. James M. Helm	One 6-pdr., two 1-pdrs.	5	51
	" "	Lt. Wm. H. H. Southerland	Four 6-pdrs., two 6-mm. Colts	5	60
ins	Protected cruiser	Capt. W. M. Folger	Six 6-in. r. f., four 4.7-in. r. f., ten 6-pdrs., four 1-pdrs., four Maxims, two field guns	300 officers and men	
	.....	.....	.....	6	—
ck	Auxiliary gunboat	Lt. C. W. Jungen	One 3-pdr., one Gatling	1	25
	Gunboat	.....	One gun †	2	9†
	Auxiliary gunboat	Lt. A. Ward	Four 6-pdrs., two 6-mm. Colts	5	51
	Gunboat	.....	Three guns †	8	32†
	Hospital ship	Comdr. A. Dunlop	.....	5	—
t	Water boat	Mate Cleveland	One 6-pdr., one Colt	1	12
	Gunboat	Lt. Com. W. C. Cowles	Two Long Toms, one stern chaser, four Maxims	.....	
h	Auxiliary gunboat	Lt. J. G. Evans	One 1-pdr., one Gatling	1	12
	Auxiliary cruiser	Comdr. W. H. Brownson	Ten 6-in., six 6-pdrs.	N. Y. Naval Militia	
	" "	Comdr. C. J. Train	Eight 6-in., two 5-in. r. f., six 6-pdrs.	Mass. Naval Militia	
	" "	Comdr. W. H. Emory	Ten 5-in. r. f., six 6-pdrs.	Mich. Naval Militia	
	" "	Comdr. C. H Davis	" " "	Md. Naval Militia	
s	Auxiliary gunboat	Ensign W. S. Crossley	One 6-pdr., one 6-mm. Colts	1	12
	Gunboat	.....	Four guns †	.....	
	"	.....	.....	2	8†
	"	.....	One gun †	7	32†
	Auxiliary gunboat	Lt. J. Hood	Two 6-pdrs , two 6-mm. Colts	5	42
	Gunboat		One gun †	2	9†
	Auxiliary gunboat	Lt. A. Sharp	.....	.....	
	Collier	Comdr. Force	.....	5	—
r	Auxiliary gunboat	Lt. Comdr. Wm. Everett	.....	4	—
	Gunboat	.....	One gun †	7	40†
	Auxiliary gunboat	Lt. Comdr. W. Kellogg	.....	4	—
r	Torpedo gunboat	Comdr. M. R. S. Mackenzie	Two 5-in. r. f., twelve 6.pdrs., two torpedo tubes, two 6-mm. Colts	9	152
	Auxiliary gunboat	.....	.....	.....	
h	Gunboat	.....	Four guns †	8	45†
c	Collier	Comdr. J. M. Miller	.....	.....	
	Gunboat	.....	One gun †	7	32†
	Collier	.....	.....	.....	
	"	.....	Two 6-pdrs.	5	48
	Dynamite cruiser	.....	One 15-in. pneumat. dynam. gun, one 4.7 and two 3.9 in. r. f., eight 6 and ten 1-pdrs., four torpedo tubes	.....	
	Auxiliary gunboat	Ensign W. R. Gherardi	One 6-pdr., one Colt	1	12
	.....	.....	.....	.....	
	Gunboat	.....	Two guns †	7	32†
	.....	Lt. Blow	.....	.....	
	Gunboat	.....	Three guns †	8	32
	Collier	.....	.....	.....	
	Auxiliary gunboat	Lt. Comdr. Marix	Four 5-in. r. f., six 6-pdrs., four 6-mm. Colts	6	—
	Collier	.....	Two 6-pdrs.	5	44
	Auxiliary cruiser	Capt. C. F. Goodrich	} Proposed one 8-in. b. l. r., five 5-in. q. f., ten 9-in.	.....	
	" "	Capt. C. D. Sigsbee	} smooth bores, — 6-pdrs.	.....	
	Auxiliary gunboat	Lt. F. R. Brainard	One 1-pdr., one Gatling	1	12
	Gunboat	.....	Three guns †	7	37†
v	Auxiliary gunboat	Lt. J. L. Purcell	One 3-pdr., one Gatling	1	12
	Gunboat	.....	Two guns †	7	32†
	Armed transport	.....	.....	.....	
	Torpedo boat	.....	Two torpedo tubes	Not in Commission	
	Despatch boat	.....	Two Hotchkiss r. f., one torpedo tube	.....	

†† Will be purchased only in case of war.

‡‡ Formerly Norwegian steamer *Solvvig*.

compartments just mentioned, and they extend along the whole length taken up by the engine and boiler compartments.

VESSELS COMPRISING AUXILIARY NAVY OF UNITED STATES.

NOTE.—The editor had hoped to be able to give a complete list of all the vessels which have recently been added to the Navy by purchase with a fairly complete description. It was found, however, entirely impracticable to do so under the pressure of other work. The following list is accurate as far as names are concerned and will, at least, be helpful in verifying the changes in nomenclature which have occurred.

Name.	Class.	Remarks.
Amazonas,	Cruiser,	now *New Orleans*.
Albany,	Cruiser,	formerly *Alm. Abrouil*.
Alm. Abrouil,	Cruiser,	now *Albany*.
Albatross,	Fish Commission.	
Alice,	Lighter,	now *Alice*.
Armeria,	Light House.	
Accomac,	Revenue Cutter,	formerly *Algonquin*.
Algonquin,	Revenue Cutter,	now *Accomac*.
Algonquin,	Tug,	formerly *El Toro*.
Active,	Tug,	now *Active*.
Atlas,	Tug,	now *Wompatuck*.
Alicia,	Yacht,	now *Hornet*.
Almy,	Yacht,	now *Eagle*.
Abarenda,	Collier,	now *Abarenda*.
Aileen,	Yacht,	now *Aileen*.
Badger,	Aux. Cruiser,	formerly *Yumuri*.
Buffalo,	Aux. Cruiser,	formerly *Nictheroy*.
Brown, W. H.,	Tug.	
Creole,	Hospital,	now *Solace*.
Chatham,	Repair,	now *Vulcan*.
Calumet,	Revenue Cutter.	
Choctaw,	Tug,	formerly *C. G. Coyle*.
Columbia,	Yacht,	now *Wasp*.
Corsair,	Yacht,	now *Gloucester*.
Corwine,	Revenue Cutter.	

Name.	Class.	Remarks.
Cæsar,	Collier,	formerly *Kingstor.*
Coaler,	Collier,	formerly *Elizabeth Holland.*
Dixie,	Aux. Cruiser,	formerly *El Rio.*
Diogenes,	Gunboat,	now *Topeka.*
Dwight, John,	Lighter,	now *Pawnee.*
Dorothea,	Yacht,	now *Dorothea.*
El Sud,	Aux. Cruiser,	now *Yosemite.*
El Rio,	Aux. Cruiser,	now *Dixie.*
El Norte,	Aux. Cruiser,	now *Yankee.*
El Sol,	Aux. Cruiser,	now *Prairie.*
Enterprise,	Tug,	now *Modoc.*
El Toro,	Tug,	now *Algonquin.*
Eagle,	Yacht,	formerly *Almy.*
Eighteen, No.,	Lighter.	
Fearless,	Tug,	now *Iroquois.*
Fowler, T. P.,	Tug,	now *Mohawk.*
Fish-Hawk,	Fish Commission.	
Free Lance,	Yacht,	now *Free Lance.*
Felicia,	Yacht,	now *Uncancomuck.*
Gedney,	Coast Survey.	
Gresham,	Revenue Cutter.	
Guthrie,	Revenue Cutter.	
Grant,	Revenue Cutter.	
Gloucester,	Yacht,	formerly *Corsair.*
Harvard,	Aux. Cruiser,	formerly *New York.*
Hamilton,	Revenue Cutter.	
Hudson,	Revenue Cutter.	
Hercules,	Tug,	now *Hercules.*
Hornet,	Yacht,	formerly *Alicia.*
Hawk,	Yacht,	formerly *Hermione.*
Hermione,	Yacht,	now *Hawk.*
Hesperia,	Collier,	now *Hesperia.*
Holland, Elizabeth,	Collier,	now *Coaler.*
Harleech,	Collier,	now *Pompey.*
Hortense,	Tug.	
Hist,	Yacht,	formerly *Thespia.*

Name.	Class.	Remarks.
Ivins, DeWitt C.,	Tug,	now *Nezinscott.*
Illawara,	Yacht,	now *Oneida.*
Iris,	Distilling ship,	formerly *Menemsha.*
Illinois,	Supply ship,	now *Supply.*
Iroquois,	Tug,	formerly *Fearless.*
Josephine,	Yacht,	now *Vixen.*
Justin,	Collier,	now *Justin.*
Kingstor,	Collier,	now *Cæsar.*
Lebanon,	Collier,	now *Lebanon.*
Luckenback, E. F.,	Tug,	now *Tecumseh.*
Luckenback, W. A.,	Tug,	now *Uncas.*
McArthur,	Coast Survey.	
Merrimac,	Collier,	now *Merrimac.*
Menemsha,	Distilling ship,	now *Iris.*
Mayflower,	Light House,	now *Suwanee.*
Maple,	Light House.	
Mangrove,	Light House.	
Manning,	Revenue Cutter.	
Morrill,	Revenue Cutter.	
McLane,	Revenue Cutter.	
McCulloch,	Revenue Cutter.	
Manly,	Torpedo Boat.	
Modoc,	Tug,	formerly *Enterprise.*
Mayflower,	Yacht,	now *Mayflower.*
Mohawk,	Tug,	formerly *T. P. Fowler.*
Niagara,	Collier,	now *Niagara.*
Nanshan,	Collier,	now *Nanshan.*
New Orleans,	Cruiser,	formerly *Amazonas.*
New York,	Aux. Cruiser,	now *Harvard.*
Nezinscott,	Tug,	formerly *Ivins, De Witt C.*
Nictheroy,	Aux. Cruiser,	now *Buffalo.*
Osceola,	Tug,	formerly *Winthrop.*
Oneida,	Yacht,	formerly *Illawara.*
Patterson,	Coast Survey.	
Prairie,	Aux. Cruiser,	formerly *El Sol.*
Panther,	Aux. Cruiser,	formerly *Venezuela.*

Name.	Class.	Remarks.
Paris,	Aux. Cruiser,	now *Yale.*
Philadelphia,	Pilot Boat,	now *Peoria.*
Perry,	Revenue Cutter.	
Powhatan,	Tug,	formerly *Penwood.*
Potomac,	Tug,	formerly *R. H. Wilmot.*
Penwood,	Tug,	now *Powhatan.*
Penelope,	Yacht,	now *Yankton.*
Pompey,	Collier,	formerly *Harleech.*
Pawnee,	Lighter,	formerly *John Dwight.*
Peoria,	Pilot Boat,	formerly *Philadelphia.*
Peking, City of,	Transport.	
Pontiac,	Tug,	formerly *Right Arm.*
Resolute,	Transport,	formerly *Yorktown.*
Rush,	Revenue Cutter.	
Right Arm,	Tug,	now *Pontiac.*
Restless,	Yacht,	now *Restless.*
Sterling,	Collier,	now *Sterling.*
Saturn,	Collier,	now *Saturn.*
Southery,	Collier,	formerly *Southery.*
St. Paul,	Aux. Cruiser,	now *St. Paul.*
St. Louis,	Aux. Cruiser,	now *St. Louis.*
Solace,	Hospital,	formerly *Creole.*
Suwanee,	Light House,	formerly *Mayflower.*
Somers,	Torpedo Boat.	
Sioux,	Tug,	formerly *Wise, P. H.*
Scorpion,	Yacht,	formerly *Sovereign.*
Sovereign,	Yacht,	now *Scorpion.*
Scindia,	Collier,	now *Scindia.*
Supply,	Supply ship,	formerly *Illinois.*
Topeka,	Cruiser,	formerly *Diogenes.*
Tecumseh,	Tug,	formerly *Luckenback, E. F.*
Thespia,	Yacht,	now *Hist.*
Uncas,	Tug,	formerly *Luckenback, W. A.*
Uncancomuck,	Yacht,	formerly *Felicia.*
Venezuela,	Aux. Cruiser,	now *Panther.*
Vulcan,	Repair ship,	formerly *Chatham.*

Name.	Class.	Remarks.
Vigilant,	Tug,	now *Vigilant*.
Vixen,	Yacht,	formerly *Josephine*.
Viking,	Yacht,	now *Viking*.
Windom,	Revenue Cutter.	
Woodbury,	Revenue Cutter.	
Winthrop,	Tug,	now *Osceola*.
Wompatuck,	Tug,	formerly *Atlas*.
Wise, P. H.,	Tug,	now *Sioux*.
Wilmot, R. W.	Tug,	now *Potomac*.
Wittick, Mary,	Tug.	
Wasp,	Yacht,	formerly *Columbia*.
Yosemite,	Aux. Cruiser,	formerly *El Sud*.
Yankee,	Aux. Cruiser,	formerly *El Norte*.
Yale,	Aux. Cruiser,	formerly *Paris*.
Yorktown,	Aux. Cruiser,	now *Resolute*.
Yumuri,	Aux. Cruiser,	now *Badger*.
Yankton,	Yacht,	formerly *Penelope*.

AUSTRIA.

Armored Cruiser.—In the early part of April, an armored cruiser was launched at Trieste, which is an enlarged *Maria-Teresa*. It is 700 tons larger and has 2,000 more horse power. Length, 392 feet; beam, 55.5 feet; draught (aft), 20.3 feet; displacement, 6,200 tons. There is a complete water-line belt of Harveyized nickel steel, 10.6 inches thick amidships, and armored bulkheads, 8 inches thick. The protective deck is 1.5 inches thick.

The engines are, of course, twin-screw, and are vertical and triple-expansion, intended to develop 12,300 I.H.P., and give a speed of 20 knots. There are eight cylindrical boilers.

There will be two 9.6-inch breech-loading rifles in a turret forward and the same aft, worked by electric gear; eight 6-inch rapid-fire guns in the armored redoubt, the four middle ones in sponsons, and with 2-inch shields; four 3-inch rapid-fire guns on the upper deck, and fourteen 47-millimeter rapid-fire guns on the superstructure. There will be two machine guns and four torpedo tubes.

Shipbuilding Program.—It is proposed to ask an appropriation for an increase of the Navy. The program includes five battleships, five cruisers, eight destroyers, and sixty torpedo boats, the whole to be completed in ten years.

ENGLAND.

Cressy Class of New Armored Cruisers.—The Admiralty have recently given out the orders for the four armored cruisers, which it was decided to build in July of last year, when the Treasury made a supplementary grant to the Navy. Messrs. Vickers, Sons, and Maxim, Limited, will build one of these vessels at Barrow-in-Furness, the Fairfield Shipbuilding and Engineering Company, Limited, will construct two, and the Clydebank Company, Limited, have been given the contract for the fourth.

—	*Cressy* class.	*Ariadne* class.	*Powerful* class.
Length, between perpendiculars	440 feet.	435 ft.	500 ft.
Beam	69 ft. 6 in.	69 ft.	71 ft.
Draught	26 ft. 3 in.	25 ft. 3 in.	27 ft.
Weight of hull	7,860	6,975	8,480
Displacement	12,000	11,000	14,200
Side armor	6 in.	.....	.....
Casemates	6 in.	6 in.	6 in.
Protective deck	3 in. and 2 in.	4 in. and 2½ in.	4 in.
Armament	Two 9.2-in. B.-L.; twelve 6-in. q.-f.; 17 small q.-f.; two sub. tor. tubes.	Sixteen 6-in. q.-f.; 17 small q.-f.; two sub. tor. tubes.	Two 9.2-in. B.-L.; twelve 6-in. q.-f.; thirty small q.-f.; two sub. torpedo tubes.
Indicated horse power	21,000	18,000	25,000
Speed	21	20¾	22
Normal coal capacity*	800	1,000	1,500

* The coal supply can be greatly increased, on emergency, to 2,000 tons in *Cressy* and *Ariadne*, and 2,500 tons in *Powerful* classes.

The new vessels differ from the eight ships of the *Diadem* and *Ariadne* classes in having a side armor for the greater part of the length, and as more powerful machinery is arranged for, the speed will be greater. Their armament, too, will be the same as in the *Powerful* and *Terrible*, so that while intended for cruisers they almost rank as battleships, and will be able to take a place in the line of battle. The cost, completed, including guns, will work out to about £630,000, while the *Powerful* and *Terrible* cost £750,000, and the *Diadem* class an average of about £575,000;

so that in view of the superior qualities over the latter, especially in respect of protection and speed, it will be recognized that Sir William White and Sir John Durston, the two technical officers chiefly responsible, have arranged a type of ship which will not only be efficient, but represent good value for the taxpayers' money, a point never forgotten at the Admiralty. The table on the preceding page gives a comparison between the three latest types of modern cruisers.

The details of construction are similar in all three types—double-bottom cellular system with longitudinal frames, extending up to the protective deck, or 5 feet below load line, to which the protective deck is connected, and on which the side armor in the *Cressy* class is constructed, as in all our battleships. This double construction gives a great security to the ship. All the ships are sheathed with teak 4 inches thick and coppered.

The armor belt extends for about 230 feet of the length of the ship, and is 240 pounds thick with 4 inches of backing. This belt is 11 feet 6 inches deep, extending 5 feet below and 6 feet 6 inches above the load line, the ordinary shell plating above that being 22½ pounds thick; but, as in previous cruisers, all the 6-inch guns are within 6 inch armored casemates. The belt extends to within 120 feet of the stem and 90 feet of the stern, and there extends athwart the ship a bulkhead of 200 pounds in thickness. And here it may be said that all the armor is of nickel steel hardened by the new process, which gives a resistance to penetration by projectiles quite double that possible six or seven years ago, so that the 6-inch armor here is far superior to the 10-inch armor in some comparatively recent ships. The side armor does not, as in all previous ships, terminate at the bulkheads, but is continued, although of less thickness, right to the ram, as in the new battleships of the *Canopus* class. This is of 2 inch nickel steel in addition to the shell plating, so that at least all explosive shells will be kept out of the ship. At the stern, abaft the armored bulkhead, the shell plating is greatly increased in thickness, and the protective deck reinforced with the same object in view. Here the protective deck is 80 pounds thick; whereas within the citadel, formed by the side armor and bulkheads, it is 60 pounds. The

main deck is also of more than usual thickness—40 pounds—to assist in protection, while, as usual, the coal bunkers are arranged on either side, from all of which it will be appreciated that while giving adequate weight for a high speed, and without relinquishing one jot or tittle of the elements of strength, the Director of Naval Construction has given a protection equal to our latest battleships, and superior to nearly all preceding ships. As to the arrangement of decks—protective, lower, main, upper and boat deck—the vessels are all alike; the *Powerful* and *Terrible* only have poops.

The main armament consists of two 9.2-inch, 22-ton, breech-loading guns, each mounted in barbettes, with 240-pound nickel steel hardened, and with a gun shield of 6-inch thickness. These barbettes are within the armored bulkheads, and the 12-inch conning tower, with 3-inch armored communication tubes, is further aft. There are two bridges and two conning towers, one forward and the other aft. These main guns have an arc of training of 135 degrees on each side, and will probably have an angle of elevation of 13 degrees. For bow fire there is on the main deck a 6-inch gun on either side, and above, on the upper deck, on either side of the forecastle another, so that four 6-inch guns fire in line of the keel to 28 degrees abaft the beam. The 9.2-inch gun aft is on the upper deck—there being no poop, while four 6-inch guns also fire from astern to 28 degrees forward of the beam. There are two 6-inch guns firing on either broadside with an arc of 120 degrees. In addition, there will be twelve 12-pounder guns, two of which augment the bow fire and two fire astern. There are five other machine guns. There are two masts, but the tops only carry search lights.

The appearance of the ships will be pretty much the same as that of the *Diadem*, with four funnels for the four boiler rooms, each of which is 32 feet 6 inches long, the three after being 44 feet broad, with two rows of four boilers, and the forward compartment 34 feet broad, with two rows of three boilers. This is practically the same as in the *Diadem*, and here also special attention has been paid to ventilation, a large number of fans being provided with electric motors.

As to the machinery, the following dimensions may be tabulated:

	Cressy class.	*Ariadne* class.	* *Powerful* class.
High-pressure cylinders, inches	36	34	45
Intermediate pressure cylinders, inches	59	55½	70
Low-pressure cylinders (two), inches	68	64	76
Stroke, inches	48	48	48
Revolutions	120	120	120
Indicated horse power	21,000	18,000	25,000
Number of Belleville boilers	30	30	48
Heating surface, square feet	51,500	45,900	69,453
Grate area, square feet	1,650	1,449	2,192
Pressure at boilers, pounds	300	300	260
Pressure at engines, pounds	250	250	210
Weight of machinery, tons	1,800	1,550	2,250
Indicated horse power per ton	11.61	11.61	11.11
Square feet of heating surface per I.H.P.	2.45	2.55	2.77
Indicated horse power per square foot of grate	12.7	12.4	11.40

* The designed results are given for comparison. These were exceeded, just as the results in the *Cressy* class may be.

The engines are, as in previous cases, to be of the inverted, direct-acting type, each set having one high, one intermediate and two low-pressure cylinders. In the *Cressy* class one of the low-pressure cylinders is to be placed forward of the high-pressure and the other aft of the intermediate cylinder. The crank shaft will be in two interchangeable parts, each part having two cranks placed directly opposite. The Yarrow-Schlick-Tweedy system is to be adopted in some of the ships. The propellers work inwards, and the starting platform is to be at the center of the ship. The cylinders will be supported in the front by wrought-steel pillars, the back columns will be cast iron, connected at the top by suitable tie-plates. The frames for the main bearings will be of cast steel tied together, each set of engines being independent of the other. The valves of the high-pressure and intermediate cylinders will be of the piston type, one to each cylinder. Those for the low-pressure will be of the double-ported flat form (one to each cylinder), with a relief ring at the back. All the valves will be actuated by means of double eccentrics and link motion, separate provision being made for adjusting the cut-off in each

cylinder. The valve setting will be arranged so that the power developed by the two low-pressure cylinders combined shall equal that of the high or intermediate cylinders.

Each set of main engines will have one vertical air pump worked by means of links and levers from the high-pressure crosshead. The main condensers are to have a total cooling surface of 21,000 square feet. The two auxiliary condensers will have 3,000 square feet of cooling surface. There will be four circulating pumps with 48-inch runners, the duty being 1,400 tons from the bilges per hour.

The crank shafts are to be of 19 inches external diameter with a 10-inch hole, the crank pins of 21 inches external diameter with 12-inch hole, those for the high-pressure and intermediate-pressure engines being 24 inches long, and for the low-pressure, 16 inches. The main bearings are to have a total length of about 14 feet, and the thrust surface will be 2,500 square inches. The propeller shaft is to be $19\frac{1}{2}$ inches external diameter, with a $10\frac{1}{2}$-inch hole. The propellers are to be about 18 feet in diameter.

As indicated in the table, there will be thirty boilers of the Belleville type with economizer; the heating surface in the steam-generating tubes will be 33,500 square feet, and in the economizer small tubes 18,000 square feet, a total of 51,500 square feet; the grate surface being 1,650 square feet. The tubes will be solid drawn, $4\frac{1}{2}$ inches external diameter for the generators and $2\frac{3}{4}$ inches for the economizers. The fans for the stokehold will be of the double-breasted type; twelve of them will be 6 feet 6 inches in diameter and four of them 6 feet in diameter. The two pumps for the hot well will be of the crank-shaft type, while there will be eight feed pumps. The capacity provided for feed water is 116 tons. The grease extractor will have 15,750 square inches of filtering area. There will be four fire and bilge pumps having a duty of 100 tons per hour.

Of the other auxiliary machinery, it may be said that there will be four evaporators of 108 tons capacity, two distillers of 54 tons capacity, three electric-light generators, two steering engines, two sets of air-compressing pumps and four reservoirs, two boat hoists,

two refrigerating engines of the cold-air type, coal hoists, ash hoists, &c., as usual.—"Engineering."

Hermes.—The Fairfield Shipbuilding and Engineering Company, Glasgow, launched on the 7th of April the second-class cruiser *Hermes*, one of two of the same type ordered last spring. The keel was laid down on April 24, 1897, so that the vessel, of 5,600 tons displacement, has been launched within a year, notwithstanding the drawback of a fire which destroyed all the machinery and patterns, and delayed the work in the initial stages. This is the second cruiser launched this year, the first having been the 11,000-ton *Argonaut*, and in six weeks they will launch a third, the *Highflyer;* while in the same period they expect to lay the keel of two 12,000-ton armored cruisers, to be called the *Cressy* and the *Aboukir*. It may be interesting to compare the *Hermes* with some earlier second-class cruisers, to show the great progress which has been made under the régime of the present technical advisers of the Admiralty.

	Magicienne.	*Latona* class.	*Hermes.*
	1887.	1890.	1898.
Length between perpendiculars	265 feet	300 feet	350 feet
Beam	42 feet	43 feet	54 feet
Draught (mean)	17 feet 6 inches	16 feet 6 inches	21 feet
Displacement	2,950 tons	3,400 tons	5,600 tons
Speed	19 knots	20 knots	19.5 knots
Protection	1½-inch deck	2-inch to 1-inch deck	1½-inch to 3-inch
Armament	Six 6-inch breech-loading guns, Nine 6-pounder quick-firers, One 3-pounder, One machine gun, One boat gun, Two torpedo tubes.	Two 6-inch quick-firers, Six 4.7-inch quick-firers, Eight 6-pounder, One 3-pounder, Four machine guns, One boat gun, Four torpedo tubes.	Eleven 4.7-inch quick-firers, Eight 12-pounders, Seven 3-pounders, Four machine guns, One boat gun, Two submarine tubes.
Normal coal capacity	400	400	550
Complement	218	273	450

The design of the *Hermes* in one or two respects introduces improvements on the *Venus* class, of which the Fairfield Company built two, and of which, in all, nine were constructed, the most notable change being in respect of guns and protection. In the *Venus* there were five 6-inch and six 4.7-inch quick-firing guns, and whereas in the new vessel it has been considered de-

sirable, in the interests of uniformity and to secure a larger supply of projectiles, to make all the guns of 4.7-inch caliber, these latter fire a 45-pound instead of a 100-pound shot; but the difference in energy is not quite so great, the former having a penetration at the muzzle equal to 11.9 inches, as compared with 16 inches of wrought iron, but there is a compensating advantage in greater rapidity of fire. In the auxiliary armament there is no change. In the *Venus* there was an armored cofferdam for the protection of the cylinders; but in the new ships the protective deck is raised to suit this change. The table we have given, however, shows the remarkable advance in second-class cruisers in ten years. The *Hermes* is 85 feet longer than the *Magicienne*, 12 feet more beam, while the displacement is almost doubled, the draught being increased by 3 feet 6 inches. This difference in weight represents superior qualities in every respect, in armament, in defence and in radius of action. Some time ago we had occasion to compare the *Doris* with the *Latona* class (see "Engineering," Vol. LXI, page 776), but the ten years' advance is still more striking.

In the first place, the increased size of the hull gives not only a steadier, but a higher, freeboard. The guns on the poop and forecastle of the *Magicienne* were 18½ feet above the water line; in the *Hermes* they are 28½ feet above the load line forward and 19¼ feet aft. As regards the attack, it will be seen that the new ships are immensely superior. They have eleven 4.7-inch quick-firers, against the six old 6-inch breechloaders. Three of the 4.7-inch guns fire ahead in line with the keel, and three fire aft. The guns on either side are built partly on sponsons on the upper deck level, the bow guns having a radius of 6 degrees abaft the beam, and the after guns of 60 degrees forward the beam. The other 4.7-inch weapons are mounted on the broadside with a large arc forward and abaft the beam. These guns are all protected by 4½-inch armored shields. Two of the 12-pounder guns fire forward and two aft, the others being on the broadside, while the most of the 3-pounder guns are in the military tops. As to the supply of ammunition, the *Hermes* has magazines 58 feet long in the forward part and 42 feet aft, in all, 100 feet, while in the *Magicienne*

the combined length was only 54 feet, 28 feet forward and 26 feet aft. The increased beam (12 feet) also adds greatly to the area of the magazines.

As to protection, there is an armored deck extending right fore-and-aft, curving 5 feet below the water line at the sides, and in the center it rises 1 foot 6 inches above it. This deck ranges from 3 inches to 1½ inches in thickness, covering the whole of the propelling and steering machinery, boilers, magazines, &c. Reserve bunkers are on the protective deck over the machinery space, and, whilst affording a water-line belt of coal protection, they give additional security in the event of damage, as they are subdivided into water-tight compartments. An armored conning tower of Harveyized steel is placed forward, fitted up with the usual means of navigating the vessel and directing operations while in action. The whole of the connections with the conning tower are protected by a steel tube extending to the protective deck. The Harveyized armor for this tower was supplied by Messrs. William Beardmore & Co., Glasgow. Bridges are fitted both at the fore and after ends for navigating the vessel under ordinary conditions, with the usual compasses, steering wheels, &c. Three search lights are operated from these bridges.

As to the hull, it may be said that it is built of Siemens-Martin steel throughout, on the usual principle adopted in warship construction. There is a cellular bottom extending the full length of the engine and boiler spaces, and before and abaft these the water-tight flats of the magazines, &c., continue the double-bottom construction right to the stem and stern. Under the protective deck the side compartments for the full length of the boiler space are utilized for stowing coal, the normal capacity being 550 tons, although this quantity may be doubled by carrying fuel on the protective deck, as already indicated. The hull is subdivided by longitudinal and transverse bulkheads into numerous water-tight compartments, the water-tight doors being worked from the main deck as well as from below. The stern posts, struts, stem and rudder are of phosphor-bronze. The stem is of the usual ram form, and the structure behind is especially strong and efficiently connected to the general framework of the vessel, with a

view to the contingency of ramming. The rudder is of the balanced type, and controlled by Harfield's compensating gear below the protective deck. The vessel, being intended for foreign service and long cruises at sea, in which the maintenance of a uniform speed becomes essential, has been completely covered to above the load-water line with teak of a minimum thickness of $3\frac{1}{2}$ inches and coppered. To secure steadiness of gun platform, so necessary in a vessel intended for war purposes, bilge keels 23 inches deep have been fitted for a length of 140 feet.

As to the machinery, it is still more interesting to compare the ship now launched and the predecessors of the same class, the *Marathon* and *Magicienne*, built ten years ago, and the *Venus* and *Diana*, completed in 1896. The table appended shows the leading dimensions in the respective classes.

—	*Magicienne.*	*Venus.*	*Hermes.*
	1889.	1896.	1898
Diameter of high-pressure cylinders	34½ inches	33 inches	26 inches
Diameter of intermediate pressure cylinders	56 inches	49 inches	42 inches
Diameter of low pressure cylinders	76½ inches	74 inches	(2) 48 inches
Length of stroke	3 feet	3 feet 3 inches	2 feet 6 inches
Indicated horse power	9,000	9,600	10,000
Steam pressure	155 pounds	155 pounds	300 pounds reduced to 250 pounds at engines
Number of boilers	4 double ended	8 single ended	18 Belleville
Total heating surface	13,600 square feet	18,740 square feet	24,020 square feet
Total grate surface	535 square feet	634 square feet	796 square feet
Ratio of grate area to heating surface	1 : 25.42	1 : 29.56	1 : 30.15
Indicated horse power per square foot of grate area	16.82	15.14	12.56
Heating surface per indicated horse power	1.51	1.95 square feet	2.40 square feet
Indicated horse power per ton of boilers	.....	17.3	22.2
Indicated horse power per ton of all machinery	.....	10.43	11.50

The first striking feature is the increase of steam pressure which has characterized all the ships built during the last four years, and is entirely due to the adoption of the water-tube steam generators. The *Hermes* has the Belleville boiler fitted with economizers, whereas the *Magicienne* had double-ended multitubular boilers, and the *Venus* and *Diana* single-ended

multitubular boilers. The result of the increased steam pressure is reflected in the ratio of the volumes of the high and low-pressure cylinders, which, in the case of the *Magicienne*, is one to 4.917; in the *Venus* one to 5.028; and in the *Hermes* one to 6.81. The *Hermes* has two low-pressure cylinders to each set of engines, which is now the universal practice in the Navy. In the matter of framing and material there has been no important change.

The increase in pressure, and the adoption of water-tube boilers, of course, has had a material influence in the reduction of weight. The total weight of the machinery in the case of the *Venus* and *Diana* was 920 tons, and in the case of the *Hermes* 870 tons; and it will be seen that whereas the *Venus* only developed 9,600 horse power under forced-draft conditions, the ship now building will under natural-draft conditions develop a power of 10,000. The reduction in weight is entirely due to the boilers, and notwithstanding the increase in power, the complete boiler installation in the *Hermes* weighs only 450 tons, against 555 tons in the *Venus*.

There are eighteen Belleville boilers in the *Hermes*, with nine elements in the steam generator, the tubes in this case being, as is usual, of solid-drawn steel, and 4 inches external diameter; while in the economizers there are nine elements, the tubes being $2\frac{3}{4}$ inches external diameter. The space between the two forms the combustion chamber. In this type of boiler the width of the fire grate is 8 feet, and the length of the fire bars is 5 feet $6\frac{3}{8}$ inches. The boilers are arranged in separate compartments, there being six in each boiler room, arranged athwartships with the tubes running fore-and-aft; there are three funnels, which are carried down to the top of the economizers. In each stokehold there is fitted a Weir's feed pump, compressed air blowers for supplying air to the furnaces and combustion chambers, and fans for ventilating the stokehold, but the stokeholds are open. The coal bunkers are arranged on either side of the stokeholds, with an athwartship bunker at the forward end.

Turning now to the engines, it may be said that the cylinders are separate and independent castings bolted together, each fitted

with a cast-iron barrel or liner, and arranged for jacketing in all cases. The cylinders and valves are arranged as follows, starting from the forward end: Flat slide valve, low-pressure cylinder, high-pressure cylinder, piston valve; piston valve, intermediate-pressure cylinder, low-pressure cylinder, flat valve. The two forward cranks work opposite to each other, and are arranged as close to each other as the centers of the cylinders admit. The other pair are similarly arranged, and have the cranks at right angles to the forward cranks. All the valves are controlled by the usual double eccentric and link-motion gear. In front the cylinders are supported on forged steel columns, while at the back the usual cast-iron A-frame is adopted.

The condensers are of brass and placed in the wings, the steam being condensed outside the tubes. The two centrifugal pumps are of gun metal, and each is worked by an independent engine, but a cross connection has been arranged so that either or both condensers may be supplied with cooling water from either pump. The feed, bilge and hot-well engines are also independent, and an auxiliary condenser is fitted in each engine room with separate circulating and air pump for the auxiliary machinery.

The shafting is of forged steel, the cranks being 13 inches in diameter with an 8-inch hole, the line shafting is 12 inches in diameter with an 8-inch hole, and the propeller length is 14¼ inches in diameter with a 9-inch hole. The propellers are of gun-metal, each having three adjustable blades, the diameter being 12 feet 9 inches and the pitch 13 feet 6 inches, and when running at a speed of 180 revolutions per minute the ship is expected to attain a speed of 19½ knots.—"Engineering."

Illustrious, a battleship of the *Majestic* class, has completed her trials, and is preparing for commission. The results of the gunnery trials mark a very pronounced step in advance, for as a consequence of the introduction of many mechanical devices, the 12-inch, 46-ton, breech-loading guns were fired with a rapidity which almost justifies their being classed as quick-firing weapons. The guns are of the ordinary service type, firing an 850-pound projectile at a muzzle velocity of 2,367 foot seconds, equal to an energy of 33,020 foot tons; and yet so complete is the operative

mechanism that the only manual effort involved is the lifting of the charge of cordite in halves, each weighing 83 pounds, from the pockets in the loading hoist on to the loading tray. The two guns in the after turret were fired three times in 107 seconds from the first discharge to the last; the time between the second and third rounds was only 49 seconds, and this was accomplished by the ordinary crew from H. M. S. *Excellent* after only two or three days' practice. Doubtless, the ship's own company, when they get accustomed to the work, will improve upon this performance; but, as it is, it means that from the forward and after turret, trained on the enemy, 10,200 pounds of shot can be delivered in 107 seconds, and there is no reason why this rate should not be continued. This, when the energy (396,240 foot tons) is noted, constitutes a vigorous attack which no ship could survive.

While the gun and turret mechanism was designed by the late firm of Sir Joseph Whitworth & Co., at the Openshaw Works, prior to the amalgamation with the Armstrong Company, there is a certain appropriateness in the association of this advance in progress with the name of Armstrong, for it was Lord Armstrong who advocated and introduced the rapid-firing type of gun into naval warfare for guns of lighter caliber. Its immense importance was fully demonstrated during the recent conflict between China and Japan, and now the united firms have attained a like result with guns of large caliber, for, considering the weight of gun and ammunition, the rate of fire attained on these trials may, as we have said, be classed as "quick firing."

As we have said, the 12-inch guns of the *Illustrious* are similar to those in the other ships of the class—of 46 tons, wire-wound, and of Woolwich pattern, with the Woolwich hand-breech mechanism, which latter differs from the type previously employed. The older breech-loading guns, it will be remembered, had a mechanism with two distinct operations—the rotating of the screw plug by a Stanhope lever, and its withdrawal by the operation of a crank handle which first drew the plug to the rear, and afterwards swung the block and carrier ring about the axis pin, clear of the box. The new mechanism has a continuous motion operated by a hand wheel, and effects the same functions as the

old gear, but in a much shorter time, about 8 seconds when the gun is about the horizontal position, but a longer time is taken when the gun is being run in or out at the same time, or is at elevation.

Two guns of this type are fitted *en barbette* forward and two aft, both with armored protecting hoods, and the mountings for the *Illustrious*, as well as those for the *Cæsar*, were supplied from the Openshaw Works. They resemble in general idea the mountings fitted to the *Barfleur*, *Centurion* and *Renown*, and fully described in "Engineering,"* but many modifications have been introduced, and to these special reference may here be directed. The *Centurion* class carried 10-inch guns, and the operations of loading, etc., were performed primarily by hand gear, whereas in the new ships hydraulic power is used, the weights to be dealt with, both in respect of gun and ammunition, being considerably heavier. The point of similarity between the two types of ships is that the shell chamber is carried underneath the gun platform, as described in our article on the *Barfleur's* gun mounting. The "ready supply" of ammunition is carried in this shell chamber and conducted directly to the loading position by hoists, so that the essential principle of all-round fire and loading at any position of training, is maintained. In the *Centurion* class the weapon was balanced about its trunnions; but in the new ships, with the heavier ordnance, the gun and slide are balanced about the trunnions of the slide, so that the effort of elevating is minimized, a necessity in the case where the hand gear has to be resorted to in the event of any mishap to the hydraulic mechanism. The whole system of mounting, too, is balanced about its center of rotation to meet the same desideratum. The center of gravity coincides as nearly as possible with the center of rotation, so that any heeling of the ship, permanently or temporarily, does not affect the force to be exerted in training the gun.

The powder is carried, as usual, in the magazines, whence it is brought to the shell chamber by hoists working in a fixed central tube. Other hoists in the same tube bring shell, should the supply in the shell chamber become exhausted. The powder

* See "Engineering," Vol. LVII, pages 358 and 415.

and shells thus brought up the central tube are transferred, as in the case of the ships of the *Centurion* class, to the hoists in the rear of the guns, which hoists act as loading trays when in their proper position. But in the case of the *Illustrious*, the hoists are operated by hydraulic power instead of by hand or electrical power. The transport of shell in the shell chamber is also effected by two hydraulic power cranes, which transfer the shell from the bins or pockets and deposit them upon the loading trays on the upper hoists. The charges brought up at the last moment through the central tube are of sufficiently small weight to be readily handled and quickly transferred to powder pockets in the loading hoists, from which hydraulic rammers on the turntable push the shell and charge into the gun. In the event of the whole hydraulic system being disabled, the guns can still be loaded by hand power, an upper loading position and loading tray being provided for each gun within the hood, and simple means are adopted for hauling the shell from the shell chamber, or the magazine, to this upper loading position, when, as in the case of the *Centurion* class, they can be pushed into the gun by hand rammers.

The rotation of the turret is effected by hydraulic turning engines, so arranged that when the hydraulic power is cut off from the engine, a powerful brake holds the turning mechanism and prevents further rotation. On the gun platform is an auxiliary hand pump, which can be operated by the gun's crew and thus run the gun in and out, elevate the gun, or open the breech, to which the hydraulic mechanism is applied. The brake system for controlling the recoil of the gun is independent of the run-in-and-out system; the brakes are self-contained and control the recoil very much in the same way as in an ordinary hydraulic recoil mounting, while the run-in-and-out system is connected with the service pressure from the main pumping engines, and serves for maneuvering the gun on its slide in either direction, or this may be done by hand gear, but much more slowly. In this connection it may be stated that the slight break-down in the case of the *Cæsar* a few weeks ago, about which so much was made in the daily press, was not in

connection with the general design of the mounting at all. The *Cæsar* had long since successfully passed through her gunnery trials, but on the occasion of the commissioning trials in January, it was decided to try, experimentally, a new form of valve on the run out cylinder, but this proved unsatisfactory. The valve fitted on the *Illustrious* differs from the form experimentally tried, and, indeed, the *Cæsar* was fitted with the same valve as the *Illustrious*, with equally good results.

In addition to the hand gear for the breech mechanism, hydraulic gear is fitted, the hand gear being arranged so that it can be disconnected. The hydraulic is more rapid in its operation; the breech can be opened or closed when the gun is at its maximum elevation—13½ degrees—in 5 seconds. Not only so, but the operation of opening or closing can proceed during the period when the gun is being brought to the loading or firing position, which effects a saving in time in the manipulation of the gun. In effect these hydraulic operations render the 12-inch gun with its high ballistic qualities a quick-firing weapon; no effort being involved on the part of the gunner, except in the pulling of the levers, admitting water pressure to the rams operating the mechanism. The control of the mounting is effected, as usual, from two sighting stations, one on each side, to which positions are brought the various levers and hand wheels for training and elevating the guns, as well as the automatic sights. The operating levers for controlling the hoists, rammer and running in and out of the gun, are conveniently placed in rear of the sighting station of the gun platform within the view and control of the captain of the turret. Auxiliary elevating levers are also provided on the gun platform, and there is a complete duplicate service of hydraulic-pressure pipes in addition to the usual central pivot supply.

At the official trial, several rounds were fired first from the guns in the fore barbette, to test the effect on the decks of the ship. The first shot was fired from the right gun at 80 degrees before the beam, with an elevation of 1½ degrees. The left gun was next fired with a reduced charge on the same bearings. In the third round the right gun fired a reduced charge

with ½ degree elevation, and in the fourth round the left gun fired a full charge at 1½ degrees elevation. The fifth and sixth rounds were fired right ahead with about ½ degree of elevation, and, as it was found that no material damage was done to the decks, further trials on this score were deemed unnecessary. The two guns were next fired with the hand gear alone in use, both guns being fired simultaneously, the left gun at extreme depression and the other at extreme elevation. The object of the trials of the two after guns was to determine the time required, and in this respect an unparalleled record was made.

The guns were fired simultaneously, and the time which elapsed from the firing of the first to the discharge of the third round was 107 seconds, during which six shots of 850 pounds were fired. For guns of such caliber this may be regarded as extraordinary, and is a speed which has never been approached in any navy. The time between the second and third rounds was 49 seconds, and these results, as we have already stated, were attained with an ordinary crew from H.M.S. *Excellent*, after a few days' drill. It must be borne in mind, too, that with this all-round system of loading, the gun, once it has been trained, can be kept on the enemy during the whole operation of loading, and therefore no time is lost in bringing to "bearing" between each discharge, so that for all practical purposes the rapidity of fire on trial was under conditions of warfare. The loading, too, was done with the gun at an elevation of 13½ degrees. Representatives were present from both Elswick and Openshaw on behalf of the contractors, and the trials, it may be added, have given great satisfaction to the authorities and all concerned.

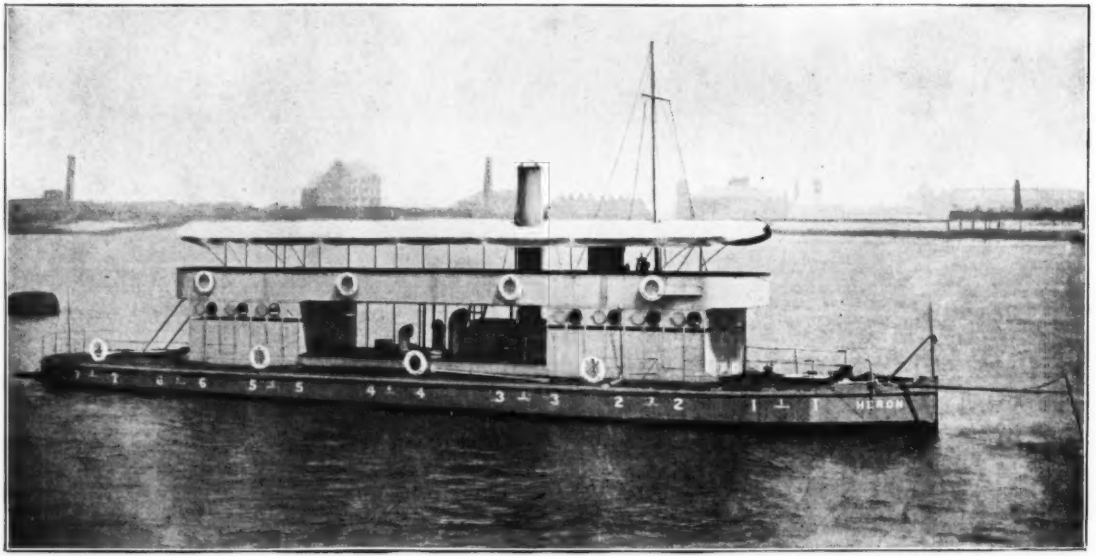
Prior to the gun trials, the *Illustrious* completed her steaming trials in the English Channel and North Sea; these were somewhat protracted, owing to difficulties experienced with the Martin's system of induced draft fitted. The engines were constructed by Messrs. Penn & Sons, Greenwich, who were represented by Mr. J. Dixon, the manager of Messrs. Penn. The engines are of the triple-expansion type, with cylinders 40 inches, 59 inches, and 88 inches in diameter by 4 feet 3 inches stroke, and were designed to develop 10,000 indicated horse power on an eight hours'

natural-draft trial, and 12,000 indicated horse-power on an induced-draft trial of four hours' duration. The designed speed

Description of trial	30 hours' coal consumption.	8 hours' natural draft.	4 hours' induced draft.
Draught of water { Forward	25 feet 7 inches.	25 feet 11 inches.	25 feet 5 inches.
Draught of water { Aft	26 feet 6 inches.	26 feet 6 inches.	26 feet 6 inches.
Actual load on safety valves, pounds	155	155	155
Vacuum in uptakes, inches of water	nil	1.6	1.96
Average pressure in boilers	142	147	152
Average pressure at engines	140	145	151
Receiver pressures, { H.P.	139	144	148
Receiver pressures, { I.P.	31	57	64
Receiver pressures, { L.P.	4	13	17
Average vacuum, inches of mercury	26.5	27.2	27.2
Mean cut-off in high pressure cylinders	40 per cent.	64 per cent.	.....
Mean pressure in cylinders { H.P.	43.45	49.05	56.15
Mean pressure in cylinders { I.P.	15.35	25.45	28.4
Mean pressure in cylinders { L.P.	7.75	12.3	14.5
Mean number of revolutions per minute	83.05	96.45	99.5
Indicated horse power, total	6,155	10,241	12,112
Force of wind	5	4	.....
State of sea	Short sea.	Smooth.	Very rough.
Coal used per indicated horse power per hour, pounds	1.77	Not taken.	Not taken.

for the former power was 16½ knots, and for the latter 17½ knots, which has easily been realized with other ships of the same class, so that there was no need to ascertain the speed on this occasion. The twin propellers have four blades, the diameter being 16 feet 11¾ inches and the mean pitch 19 feet 9⅜ inches. The results on the three trials are given in the table above. The displacement is 15,140 tons.—"Engineering."

Heron.—[Partial description in last number of JOURNAL.] This was the first of six vessels ordered by the British Admiralty from Messrs. Yarrow & Co., in the latter part of 1896. They are 100 feet in length by 20 feet beam, and constructed in eight floatable sections, like many stern-wheel steamers which this firm has constructed for the British and other governments. The hull is, as it were, cut transversely into eight parts of comparatively small size, bulkheads being provided at


HERON

the ends of each such part, which can be lowered from the deck of the transporting steamer into the water alongside and then bolted together, thus forming an entire hull of the gunboat. The whole of the boat proper is constructed of galvanized steel, which galvanizing adds greatly to the life of the vessel. The draught of water in a fully equipped and laden condition is only 2 feet, which makes these vessels most useful for ascending shallow rivers, as their speed is fairly good, viz: about 10½ miles per hour.

On the main deck of the vessel there are cabins for officers and warrant officers, and on these is a second, or battery deck, on which are quick-firing guns and rifle-caliber automatic guns. These, as well as the cabins, are protected from rifle bullets by bulwarks and shields of very hard and strong steel, which is perfectly rifle-shot proof. The steering wheel is on the forward part of the upper deck inside a bullet-proof conning tower. The vessel can be steered either by steam steering gear or by hand, and there are three rudders so as to secure great maneuvering power, which, of course, is necessary in navigating tortuous rivers. The officers have their quarters in the forward end of the vessel on the main deck, and the crew sleep under canvas on the battery deck. The holds under the main deck contain the magazines and provisions.

The propel.ing machinery consists of twin screws working in tunnels in the after part of the hull, actuated by two sets of triple-expansion, surface-condensing engines. The boiler is of the Yarrow water-tube type, arranged to work under forced draft in a closed stokehold, for which purpose there is a fan and engine on the plan of a torpedo boat. The boiler is designed for the use of wood fuel. There is a centrifugul circulating pump and engine, also an evaporator for making fresh water for drinking purposes as well as for the supply of the boilers.

The speed, fully armed and provisioned, is, as mentioned, 10½ miles per hour.

The *Heron* arrangement of propellers requires a few words of explanation: As the propellers must not project below the bottom of the boat, the draught of water (limited to 2 feet) would

not admit of a larger propeller being used than about 2 feet diameter with the usual arrangement of the stern. In order, however, to propel so large and beamy a vessel at 10 to 11 miles per hour requires two screws of at least 3 feet 5 inches diameter, which would be uncovered with water for a large part of their diameter unless the following device were adopted: The propellers work within two channels raised up in the bottom of the boat, the upper part of these being well above water. As soon as the propellers begin to revolve they rapidly expel the air from the upper part of the tunnels or inverted diving bells, and then they work in solid water, enabling them to drive the vessel efficiently, although not with equal efficiency to what it would be if the draught admitted of the ordinary screw. On the highest part of each tunnel there is an air-tight door, which is consequently always above the surrounding water, and through which access is obtained to the propellers for renewals or clearing away weeds. A propeller can be removed and replaced by another within ten minutes.

Projecting from the stem of the boat is a long, hollow steel pole, from which a steel lever hangs down to any desired depth below water. Should the vessel get into shallow water and be in danger of running aground, the lever touches first, and by means of a cord rings an alarm bell in the pilot house, thus giving timely warning to the pilot to stop the engines. This draught indicator is usually set to touch the ground at a draught of 12 or 18 inches greater than the draught of the steamer.

Another provision is made, by means of two steel poles with mushroom heads and two special winches, for pushing off or lifting the fore end of the boat from a bank, should she, notwithstanding the first-named warning device, get aground.

We have already mentioned that the crew are berthed on the battery deck under canvas, well above the river level, which is important in hot and unhealthy locations.

The canvas roof is supported by a strong wooden frame-work, from which the hammocks are slung. Every convenience is provided in the shape of lockers, mess tables, small arm racks,

etc., and the upper deck is thus converted into a cool, roomy mess room.

Two of these gunboats are on the Niger, having been put together at the mouth of that river, and in actual work this system of propulsion is giving the best possible results, the propellers being completely encased and well protected from damage.

Powerful.—The defects which are alleged to have been developed by the *Powerful*, now in Chinese waters, do not appear to be of a very serious character after all. The defects are not serious enough to incapacitate her altogether, although until they have been thoroughly remedied it would not be advisable to drive her at a very high speed. It is doubtful, too, whether proper facilities for her repair exist at Hong Kong, and it is thought by some that she will have to be sent home before her present commission is completed. Mr. Goschen states that such is not the case. The bearings appear to have been worn down internally to the extent of a small fraction, and the brasses will have to be refitted, but, as Mr. Goschen said, this is not an unusual defect after a long passage.

Mr. W. Allan, M. P., asserted that the vessel had taken ten days to steam 1,500 miles, and that the coal expenditure on the voyage had been heavy. There seems to be little doubt about this, for the cost of coal for the journey from Portsmouth to Hong Kong would seem to work out at about £11,000, or a total of about 8,300 tons.

A correspondent writing from Hong Kong states that the ship was forty-nine days seven hours under steam between Portsmouth and Hong Kong, and this would give us an average speed of just over 12 knots. The second attempt to carry out the twenty-four hours' trial ended in the ship reaching 16½ knots, which was maintained for ten hours, and then the port engine bearings gave out, and she had to stop to adjust. After this it was not considered advisable to steam at more than forty revolutions. The *Powerful* and *Terrible* were built to satisfy a certain sort of public opinion, and have neither of them been brilliant successes, but, on the other hand, it cannot be said that they are altogether failures. It is expected that when the *Powerful* has completed a year on the

China station she will proceed to Australia and serve a year there, subsequently spending another year in the Pacific.—"Marine Engineer."

The following account of the *Powerful's* trip to China is translated from "Le Yacht," which says its information is from English newspapers.

"On the 7th of October last, the *Powerful* left Portsmouth for Hong Kong *via* the Cape of Good Hope. As far as Mauritius the speed was to be moderate, but during the run from Mauritius to Hong Kong there was to be a 24-hour's trial at maximum speed. The Admiralty wished to show, if not the speed, at least the endurance, and the ability to reproduce at any time the power and speed of the acceptance trials, 25,000 I.H.P. and 21.5 knots. The effort was a failure. When the attempt was made to run at full power, the best result was 18 knots and 12,500 I.H.P. The thrusts heated so badly that it was useless to attempt higher speeds.

"The ship was at Colombo sixteen days, during which the machinery was overhauled, but without success, as the thrusts again heated at the next attempt to make high speed. After ten hours at a speed of 16.5 knots, the port engine was stopped, and the rest of the trip was made with the starboard engine only, at a speed of 13 knots. The *Powerful* arrived at Hong Kong January 3, 1898, or in eighty-eight days after leaving Portsmouth.

"Although the speed was moderate, the coal consumption was excessive. On leaving Portsmouth, there were 2,800 tons in the bunkers. At Las Palmas, 800 tons were taken; at the Cape, 2,286; at Mauritius, 800, and at Colombo, 2,125, or 8,300 tons in all, worth about $50,000. Taking the coal per I.H.P. at 2 pounds, this would be sufficient for seventy-two days at 14 knots or 24,200 miles."

"Le Yacht" says that, while many English critics laid the blame for excessive coal consumption on the Belleville boilers, the general opinion is that they were not at fault, or, at least, the trouble was due to lack of sufficient experience in their working. It appears also that there was difficulty in getting an adequate supply of fresh water for the boilers.

"Le Yacht" attributes the difficulties in great measure to "the fact that war vessels are not designed to make long runs at high speed, or, in a word, to imitate the fast mail steamers." This has been shown in the case of fast vessels of other navies, and the "Yacht" cites our own *Columbia* as a case in point, saying "the Americans wanted to show that she could cross the Atlantic at the same speed as the mail boats." This, of course, is not accurate, as the *Columbia*, even with her large bunker capacity of nearly 1,700 tons, does not carry four days' coal at her top speed of nearly 23 knots.

The "Yacht" adds: "A war vessel has not, like a mail steamer, the single aim of making long voyages at a designed speed. She is intended rather to remain near an anchorage most of the time, maneuver at moderate speed, and occasionally, for a few hours, to run at very high speed. This is true of every type of war vessel, including the cruisers. Full-power steaming is the exception for war vessels, and is only obtained by exceptional means; forced draft to make up for the insufficiency of boiler power; much greater demand on the personnel (*pression de régime exagérée*); and an excessive number of revolutions to make up for the small amount of weight left disposable by reason of the exigency of military considerations to the motive machinery.

"On a mail steamer, on the contrary, the steaming speed, however high it may be, is the normal regimen, and engines and boilers are designed to secure it without effort. Moreover, on war vessels, the necessity of placing the engines below the protective deck leads to defective proportions and too short a stroke for the pistons. Likewise the excessive subdivision into water-tight compartments leads to complication of auxiliaries and piping, and adds to the chances of accident.

"There is another cause, also, from our point of view, for the superiority of the mail steamer to the cruiser for long-distance steaming at high speeds, namely, the permanence of the personnel of the engineer's force. To get the best out of any machine, it must be well understood. Like a living organism, it has its weak points and its vices, which can only be overcome by knowing them perfectly. This knowledge is easier to acquire on the mail

steamer than on the more complicated war vessel from the very nature of the two, because the engineering personnel of the war vessel changes with every commission, and station bills, however detailed, cannot replace habit and familiarity.

"Moreover, the maintenance of the machinery is much easier on mail steamers than on war vessels. The former are in port after every trip, and their machinery can be inspected and thoroughly overhauled. On war vessels, repairs are always hasty, provisional and often insufficient.

"Finally, war vessels are at a great disadvantage as compared to the mail steamers with respect to getting the coal to the fires as soon as it is necessary to use the supplementary bunkers. This is due to the smallness of the bunkers on account of the water-tight subdivision, which also makes access difficult. Although this was not a cause of the troubles on the *Powerful*, it was a very important factor in the *Columbia's* fast run across the Atlantic, when fifty additional coal passers were sent from the deck force.

"The experience of the *Powerful* shows the utter worthlessness of figures of large radii of action at economical speed. Such figures may be useful in comparing different ships, but they do not represent actual facts. We learn, also, that any maritime power must possess numerous stations for coaling and repair if it expects to operate away from home."

Terrible.—An exhaustive series of trials of the auxiliary engines of the *Terrible* has been made, and the results corresponded with those of the *Powerful*, of which the coal consumption amounted to 40 tons a day for auxiliary engines when on her way to China. The trials of the *Terrible* were of a varied character, the after and the forward boilers being tried independently. The fan engines were not tested, but the most extensive trial of the series consisted of a test of the evaporator, electric-light and refrigerating machinery, when it was found that for these engines alone the consumption amounted to 27 tons of coal per day. Each of the series extended over a period of eight hours, and in order to reduce the coal consumption it has been decided to recover the steam pipes. The vessel will then proceed to sea for a series of further experiments, and, according to

present arrangements, will take part in this year's maneuvers. Her complement has been increased from 840 to 900; the engine-room and stokehold staffs have been increased.

Woodlark.—The official two hours' trial of the *Woodlark*, one of the shallow-draught armed river steamers recently ordered by the British Government, took place on Tuesday, the 22d of February, on the Thames. The vessel, which has been built by John I. Thornycroft & Co., is 145 feet long and 24 feet broad. The draught of water was not to exceed 2 feet when loaded with 30 tons deadweight, and the speed under these conditions was to be 15 miles per hour. The mean draught of water on trial was found to be 1 foot 11½ inches, and the vessel covered 30¾ statute miles in two hours. She is armed with quick-firing and Maxim guns, and the sides above water line and the deck in way of the machinery are protected with Cammell's bullet-proof steel plating. The *Woodlark* is fitted with Thornycroft twin-screw turbine propellers in raised tunnels, and is the fastest of the gunboats of this class hitherto constructed. Her speed astern was found to be 4¾ miles per hour, and she proved to be under control when going astern.

Ariadne.—The Clydebank Engineering and Shipbuilding Company, Limited, Glasgow, launched on the 22d of March the *Ariadne*, a first-class cruiser of practically the type of the *Europa*, which was delivered for trial to the Admiralty recently and is now being prepared at Portsmouth for sea. The *Ariadne* is 462 feet 6 inches over all, and 435 feet between perpendiculars; her beam, extreme, is 69 feet, and her displacement 11,000 tons. There is a double bottom the full length of the machinery and boiler spaces, and, fore and aft, steel water-tight magazine flats continue the protection. Above the protective deck over the boiler spaces, and below alongside the boilers, are side compartments for the stowage of coal; and with cross bunkers there is formed as complete a protection as is possible to the boilers. At the normal draught the coal capacity is 1,000 tons, but there is provision for double that quantity of fuel should the necessity of carrying it arise.

The subdivision of the hull by longitudinal and transverse bulk-

heads is exceptionally complete, and with so many water-tight compartments the vessel is as nearly unsinkable as a warship may be. In the bulkheads, openings have been cut only where they are likely to be absolutely necessary, and the water-tight doors which have been fitted may be worked both on the spot and from the main deck. As is usual in warships that are sheathed, the stem, stern-post and shaft-brackets are of phosphor-bronze. The hull, up to about 6 feet over the water line, is sheathed with teak planking, which, when the dockyard takes the vessel over, will be coppered. There are bilge keels about 210 feet long and 3 feet deep. The rudder is a casting of phosphor-bronze plated with naval-brass, and may be worked either by screw-steering gear actuated by duplicate engines, one in each engine room, or by hand. All the steering apparatus is below the protective deck, which has a thickness ranging from 4 inches amidships to 2½ inches at the ends, extends the whole length of the vessel, and covers completely the machinery, boilers and magazines. The conning tower is of Harveyized steel, and the steering gear, shafting, voice tubes, &c., are protected, as far as the protective deck by a steel tube 7 inches thick. The navigating bridges are as in other ships of the Navy, but in the *Ariadne* the after one is higher in order that the view of officers may not be obstructed by other deck erections and fittings.

When the vessel is completed her armament will be: Four 6-inch quick-firing guns with shields, two on the upper deck aft and two on the forecastle deck; twelve 6-inch quick-firing guns in armor casements of Harveyized steel, eight on the main deck and four on the upper deck; fourteen 12-pounders and a large number of smaller and machine guns. There will also be two torpedo tubes, discharging under water forward. The complement of the vessel is about 700 officers and men, and, in addition to the accommodation for them, there is a suite of rooms for an admiral.

The machinery consists of two sets of triple-expansion engines fitted in two water-tight compartments; each set has four inverted cylinders working on four cranks. The high-pressure cylinder is 34 inches in diameter, the intermediate 55½ inches in

diameter, and each of the low-pressure 64 inches in diameter. All are adapted for a stroke of four feet. The cylinder covers are of cast steel, and the pistons, of conical shape, are also of cast steel. The high and intermediate cylinders are fitted with piston valves, and the low-pressure with treble-ported slide valves, with a relieving ring at the back, all the valves being worked by the usual double-eccentric and link-motion gear. Reversing is effected by means of double-cylinder steam engines, with gear of the all-round type, hand-gear also being available. The sole-plates are of cast steel, and the cylinders are supported by cast-iron columns at the back, and forged-steel columns at the front. The main condensers are at the back of the engines, and constructed of cast brass in oval form; they are fitted with brass tubes $\frac{5}{8}$ inch in diameter. The condensing water is supplied by four centrifugal pumps of gun-metal, fitted with independent engines. Steam will be supplied by thirty water-tube boilers and economizers. The boilers are arranged in four groups, each group fitted in a water-tight compartment. They are designed to work at 300 pounds pressure, reducing valves being fitted to reduce the steam pressure to 250 pounds at the engines.

Furious.—The *Furious*, cruiser, returned to Plymouth on the 16th of April from the first of her 30 hours' coal-consumption trials. The trials took place between Start Point and the Scilly Isles, under the most favorable conditions for steaming. The machinery was in charge of the contractors' staff, assisted by naval stokers from Devonport. The mean results were as follows:

Steam in boilers, pounds,	225
Steam at engines, pounds,	138
Cut-off in high-pressure cylinders, starboard, inches,	27.7
Cut-off in high-pressure cylinders, port, inches,	26.2
Vacuum, starboard, inches,	28.4
Vacuum, port, inches,	27.6
Revolutions, starboard,	87.9
Revolutions, port,	87.1

Mean pressure in cylinders, high, starboard, pounds,	40.5
Mean pressure in cylinders, high, port, pounds,	33.5
Mean pressure in cylinders, intermediate, starboard, pounds,	15.4
Mean pressure in cylinders, intermediate, port, pounds,	15.6
Mean pressure in cylinders, low, starboard, pounds,	7.4
Mean pressure in cylinders, low, port, pounds,	6.0
Indicated horse power, high pressure, starboard,	372
Indicated horse power, high-pressure, port,	304
Indicated horse power, intermediate, starboard,	371
Indicated horse power, intermediate, port,	371
Indicated horse power, low, starboard,	457
Indicated horse power, low, port,	371
Total, starboard,	1,201
Total, port,	1,046
Collective indicated horse power,	2,247
Total coal consumption per indicated horse power for all purposes, pounds,	2.35

The consumption was considered very satisfactory. The ship developed an average speed of slightly over 12 knots.

The second of her coal consumption trials, was also thirty hours, at 7,003 horse power. The course was from Start Point to the Scilly Islands, and the runs were made under the best conditions for steaming. The mean results were: Steam at engines, 210 pounds starboard, 210 pounds port; cut-off in high-pressure cylinders, 55 per cent. starboard, 54 per cent. port; vacuum, 27.8 inches starboard, 27.6 inches port; revolutions, 127.4 starboard, 128.4 port; mean pressure in cylinders, high, 72.2 pounds starboard, 73.3 pounds port; intermediate, 32 pounds starboard, 37.4 pounds port; low pressure, 15.9 pounds starboard, 14.4 pounds port. The indicated horse power was, high pressure, 962 starboard and 986 port; intermediate, 1,113 starboard and 1,312 port; low pressure, 1,452 starboard and 1,330 port; total, 3,527 starboard and 3,628 port, making an aggregate horse power of 7,155. The coal consumption per indicated horse power was 2.098 pounds, and the average speed

18.7 knots. In coal consumption and speed the trial was exceedingly satisfactory. The next trial will be at 10,000 horse power.

Goliath.—The *Goliath*, which was launched at Chatham on the 23d March, is one of six battleships, the other five being the *Canopus*, building at Portsmouth; the *Ocean*, building at Devonport, and the *Vengeance*, *Albion* and *Glory*, building at Barrow, Blackwall and Birkenhead respectively. They are somewhat smaller than the *Majestic* class, but they possess the advantage of being able to steam nearly a knot faster, while the armament of the two types of ships is very similar. The chief dimensions are: Length between perpendiculars, 390 feet; extreme breadth, 74 feet; draft of water, forward and aft, 26 feet; displacement to load water line 13,000 tons.

The ship has a belt of 6-inch steel Harveyized armor, 196 feet in length, extending from 5 feet below the water line to 9 feet above it. At the ends of the belt there are rounded armor bulkheads of Harveyized steel, 12 inches, 10 inches and 8 inches in thickness. The two barbettes are protected with 12-inch armor on the upper tier of plates, and 6-inch on the lower tier, the latter being behind the side armor. The fore conning tower has 12 inch Harveyized steel armor, and the after conning tower 3-inch nickel-steel armor. The main and middle decks between the armor bulkheads are protected with plates of ½ inch and 1 inch in thickness respectively. The casemates for the 6 inch quick-firing guns are protected with 6-inch armor, with plates at the back 2 inches thick. The end main-deck casemates have novel features in that the guns can fire right forward and right aft. The contractors for the armor are Messrs. C. Cammell & Co. and Messrs. J. Brown & Co.

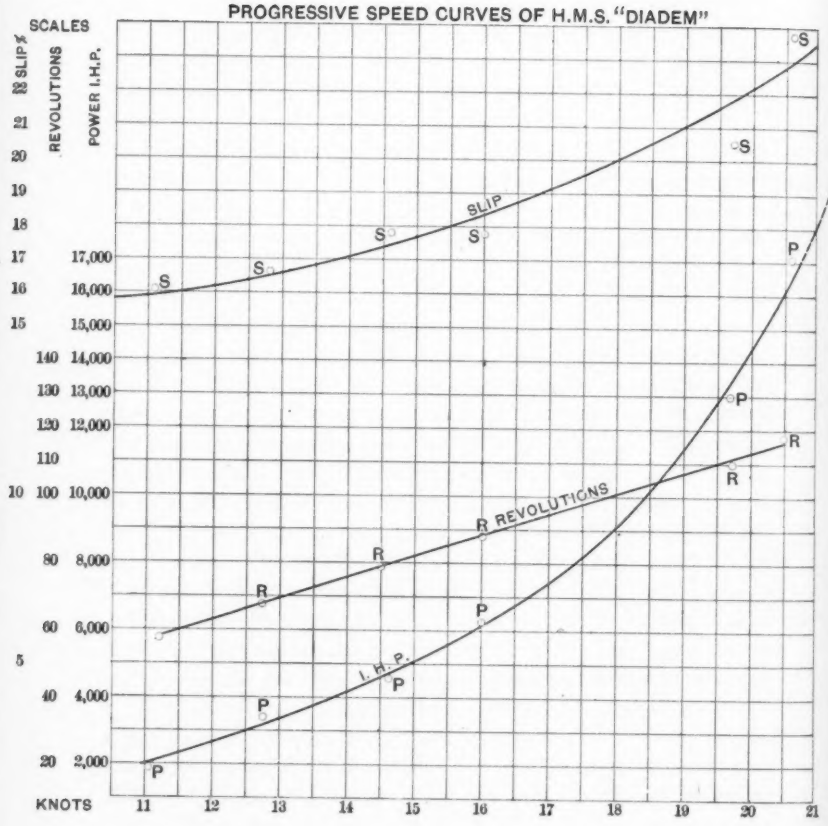
The armament consists of four 12-inch (46-ton) breechloading wire guns on turntables in circular redoubts, with all-round loading mountings, the guns being protected by 8 inch Harveyized steel shields; twelve 6-inch quick-firing guns, eight in casemates on the main deck, and four in casemates on the upper deck; ten 12-pounder guns, six on the upper deck amidships, and four on main deck, forward and aft; six 3-pounder Hotch-

kiss guns, three in military top on each mast; two 12-pounder boat and field guns, eight .45-inch Maxim guns, and six howitzers. There are four submerged tubes for firing 18-inch torpedoes, two on the broadsides forward and two aft. The ship will carry fourteen 18-inch torpedoes and five 14-inch, the latter being for firing with dropping gear from the ship's steamboats.

Messrs. John Penn & Sons are the contractors for the engines, which are of the inverted triple-expansion type. The boilers, twenty in number, are of the water-tube Belleville type, and will be placed in three water-tight compartments. The cylinders of the engines are 30 inches, 49 inches and 80 inches in diameter respectively, with a 4 foot 3-inch stroke. The twin screws are 17 feet in diameter, and arranged so that the pitch can be varied. The engines will develop 13,500 horse power, and this will give a speed of 18½ knots. The ship is supplied with the usual auxiliary machinery, refrigerating machines, electric-light plant, &c. The total coal-carrying capacity is 1,900 tons—930 in the lower bunkers abreast the machinery, 390 tons in the wings outside these bunkers and next to the skin of the ship, and 580 tons on the protective (middle) deck at the sides of the ship. This quantity of coal will enable the vessel to steam for about thirty days at 10 knots, making due allowance for coal consumption for auxiliary purposes. The ship is fitted with two steel masts and sixteen boats. The hull is constructed on the bracket system, and all work is made water tight to the height of the upper deck.

Diadem.—[Completion of account in February JOURNAL. Condensed from an article in "Engineering."]—The approximate weights of the machinery of the *Diadem* are as follows: Machinery, 575 tons; shafts and propellers, 112 tons; in boiler rooms, 750 tons; auxiliary machinery, 83 tons; together, 1,520 tons; so that the power realized on the contract full-power trial was equal to about 11½ indicated horse power per ton. The forward boiler room, which was not used in the trials with only 78 per cent. of the boiler power, occupies a length of 33 feet, and the weight is about 160 tons.

As to the radius of action, it may be said that on the thirty hours' trial, at one-fifth the full power, the ordinary rate for war-


PROGRESSIVE SPEED CURVES OF H.M.S. "DIADEM"
SCALES
SLIP %
REVOLUTIONS
POWER I.H.P.
KNOTS
SLIP
R REVOLUTIONS
I. H. P.
S
R
P
22
21
20
19
18
17
16
15
140
130
120
110
10
100
90
80
60
5
40
20
17,000
16,000
15,000
14,000
13,000
12,000
10,000
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2,000
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21

ship cruising, the coal consumption was nearly 100 tons, or, to be exact, 220,054 pounds, and during the period the vessel steamed 369 sea miles, according to two patent logs; so that the coal used was equal to 595 pounds per sea mile traveled, and it should be remembered that the weight propelled at the satisfactory rate of nearly 12¾ knots for this coal expenditure was over 11,000 tons. As the ship carries 2,000 tons under ordinary conditions, she will travel at this rate for nearly 7,500 sea miles; at 10 knots the radius would be about 11,000 miles. On the 30 hours' trial at 12,500 horse power, the vessel ran at 19½ knots, and the total distance steamed for 275 tons of fuel was 586 nautical miles; so that the radius at this speed is about 4,300 nautical miles; while with her normal coal supply, the *Diadem* could steam at full speed—20.7 knots—for about 3,000 nautical miles, and, moreover, the steady working of all the machinery on the trials showed that such a performance could from other standpoints be realized. The results of all the steaming trials have, therefore, been most satisfactory, and Sir John Durston, K. C. B., is to be congratulated on this further success of his policy. This opportunity, too, may be taken of felicitating Mr. H. J. Bakewell, one of Sir John's staff at the Admiralty, who has inspected the machinery of the *Diadem* class from the initial stages. Owing to the operation of the age regulation, this will be among the last of a long series of successes realized by Mr. Bakewell's superintendence of design and construction.

As to the speed results, these have been eminently satisfactory. We give on Table II, the mean of mean results in each case; and on the diagram opposite we have plotted out curves of revolutions, power and percentage of actual propeller slip for the progressive speeds. The vessel ran four times over the mile at Stokes Bay at about 11, 12¾, 14½ and 16 knots, while three runs were made over the deep-sea course, between Dodman Point and Rame Head, west of Plymouth, at continuous steaming power and at full power. Care was taken, as is the case with all Admiralty speed trials, to have the ship at her full load displacement, at least, or in excess of it. We may here state that the length of the ship between perpendiculars is 435 feet, the beam 69 feet,

and at 25 feet 3-inch mean draught she displaces 11,000 tons. Excepting the 11-knot runs, the measured-mile trials were made at about the top of the tide, so as to secure sufficient depth of water. In connection with the trial on the Devonshire coast on January 22, some doubt arose as to the actual time of one of the runs over the 23-knot course, and we have given the doubt against the ship, the speed of 19.72 knots being probably the more accurate of the two speeds shown in the table. This, too, is borne out by the curve showing the percentage of the slip. It could not move about so erratically as the "spots" suggest, and the difference between 20.6 per cent. and 20.9 per cent.—the latter the more probable result—gives a more regular curve.

In connection with the trial at full speed, a similar correction suggests itself. When we gave the detailed results of this trial, we showed that on the first two runs in opposite directions there was no difference in the speed. They were made in slack water, the length of the course was the same, 22.8 nautical miles, and there was only a second of difference in the time taken; the speed in each case was 20.72 knots. The third run was made against a very perceptible tide, and a desirable course would have been to make two runs, the second with the same current, so as

TABLE II.—SPEED TRIALS OF H.M.S. *DIADEM.*

Date.	Speed in knots.	Indicated horse power.	Revolutions.	Slip.	Remarks.
				p. cent.	
Feb. 5....	11.07	1,925	58.1	16.1	Four runs on measured mile (Stokes Bay).
Jan. 19...	12.74	3,184	67.3	16.6	Four runs on measured mile (Stokes Bay) during 30 hours' consumption trial.
Feb. 5....	14.59	4,448	78.1	17.8	Four runs on measured mile (Stokes Bay).
Feb. 5....	16.01	6,277	86.9	17.9	Four runs on measured mile (Stokes Bay).
Jan. 22...	19.79	13,001	109.8	20.6	Three runs on deep course of 23 knots length. There is a doubt as to the actual time of one of the runs, and the figures on the lower line are probably more accurate.
Jan. 22...	19.72	13,001	109.8	20.9	
Jan. 26...	26.60	17,079	119.0	23.7	Three runs on deep course; two in slack water, the third against tide. The mean of the first two runs is as shown on the lower line.
Jan. 26...	20.72	17,104	118.6	23.0	

to eliminate tidal influences. That would have been done, most certainly, in the merchant service. As the engine performance was remarkably uniform throughout these three runs—the mean collective powers were 17,155, 17,052 and 17,053 indicated horse power—this tidal influence alone can be accountable for the difference in speed, 20.72, 20.72 and 20.20 knots. This last run should, in fairness, therefore, be omitted in determining the true speed of the ship for the revolutions and power of the engines, in the absence of a run with the same current, and, therefore, we prefer to take the mean of the first and second runs. The results agree with the anticipations of the design: in this they only conform to the chief characteristic of all of Sir William White's ships. For 16,500 indicated horse power, 20½ knots was aimed at; with a slight addition to power, 20.72 knots has been realized, while the moderate wave formation proved the fineness of the model.

Violet, torpedo-boat destroyer, had a twelve hours' economical coal-consumption trial at Portsmouth on Wednesday, the 23d February. She was required to steam at 13 knots with a coal consumption not exceeding 1 ton per 30 miles. The mean speed of the twelve hours was 13.008 knots, and the consumption 1.99 pounds per unit of power per hour. The average worked out at 36½ miles per ton of coal, and, as the vessel carries 84 tons of fuel, this gives her a radius at economical speed of 3,066 miles.

Flying-Fish, torpedo-boat destroyer, built and engined by the Palmer Shipbuilding Company, had her initial three hours' coal-consumption trial on the 25th February. The mean of six runs over the measured mile in Stokes Bay gave her a speed of 30.361 knots, with 390.7 revolutions a minute, while with 393 revolutions for the three hours the speed by patent log was 30.484 knots. The indicated horse power on the mile was 6,431, and for the three hours 6,457, showing remarkable uniformity in both phases of the trial. There was an abundance of steam throughout the run.

Locust.—On January 31, H.M.S. *Locust* completed her official full-power speed trials on the Clyde. Six runs on the measured mile gave the following results:

	Steam.	Time.	Speed.
First mile,	210	1·58	30.51
Second mile,	220	1·59⅖	30.20
Third mile,	220	1·55	31.30
Fourth mile,	215	2·1	29.75
Fifth mile,	212	1·56	31.03
Sixth mile,	210	2·2	29.51

The mean speed thus realized being 30.49. The alternate runs were against the tide and wind, which increased as the trial progressed, causing a considerable sea and heavy dashing spray at time. The speed realized for the three hours' continuous steaming was 30.11 knots.

Wolf.—On March 9th, H.M.S. *Wolf* completed her official full-power speed trials on the Clyde in the presence of the Admiralty representatives. Six runs were made on the measured mile with the following results:

	Steam.	Time.	Speed.
First mile,	211	1·58⅕	30.46
Second mile,	212	1·56⅕	30.98
Third mile,	222	1·55⅕	31.25
Fourth mile,	215	1·54⅗	31.41
Fifth mile,	223	1·55⅕	31.25
Sixth mile,	208	1·55⅗	31.14

The mean speed thus realized was 31.2 knots. After completing the six miles, the vessel was taken outside the Cumbræ to complete the three hours' steaming at her contract speed of 30 knots, which was easily obtained, the results at the finish showing a speed of considerably over a quarter of a knot in excess of the contract. After completion of this trial, the usual steering trials at full speed ahead and astern were carried out, and the stopping, starting and reversing of the engines demonstrated for efficiency.

Mermaid.—On February 22d Messrs. R. & W. Hawthorn, Leslie & Co., Limited, launched from their Hebburn shipbuilding yard H.M.S. *Mermaid*. This vessel is the second of two being at present constructed by this firm, and is of the latest type

of torpedo-boat destroyers. Her length is 210 feet; breadth, 21 feet, and depth, 12 feet 6 inches; displacement, 308 tons. The main propelling machinery consists of two sets of vertical, triple-expansion engines of specially light design, in the construction of which steel and the strongest bronzes have been used with a view of combining lightness with strength. The engines at full power will develop 6,000 I.H.P. when running at about 380 revolutions per minute. Steam will be supplied by four Thornycroft water-tube boilers, working at 250 pounds per square inch, and arranged in two separate compartments.

Gipsy.—Lately the Fairfield Shipbuilding and Engineering Co., Limited, have completed the official trials of H.M.S. *Gipsy*, the first of the 30-knot torpedo-boat destroyers built by them for the British Admiralty, with most satisfactory results. The speed on six runs over the measured mile at Skelmorlie gave a mean of 30.176 knots. On a subsequent trial of three hours' continuous steaming the mean speed was 30.207 knots.

FRANCE.

Amiral de Gueydon.—The "Yacht" gives the following description of the first-class armored cruiser *Amiral de Gueydon*, which is building at Lorient. Length, 452 feet; beam, 63.6 feet; displacement, 9,515 tons. The machinery is building by the Chantiers de la Loire, at St. Denis. There are three triple-expansion engines and three screws. The boilers are placed both forward and aft of the engines, a custom very common in Italian vessels, as shown by the illustrations of the *Cristobal Colon* in this number. The boilers are of the Niclausse pattern. The maximum I.H.P. will be about 20,000, which is expected to give a speed of about 21 knots.

There will be a water-line belt of special steel (not Harveyized), 6 inches thick, reaching from the bow nearly to the stern, and at its after end there will be a transverse armored bulkhead. Above the belt will be a light side armor, 3.75 inches thick. There will also be the usual armored deck and a splinter deck.

The main battery consists of two 7.7-inch breech-loading rifles in turrets at bow and stern, each turret having an arc of 270

degrees; and eight 6.5-inch rapid-fire guns in armored redoubts, four firing ahead and four astern. These have an initial velocity of 2,870 foot-seconds. The secondary battery includes four 3.94-inch rapid-fire guns, sixteen 47-mm. rapid-fire guns and six 37-mm. rapid-fire guns. There will be two submerged torpedo tubes.

Dupleix.—The construction of the armored cruiser *Dupleix*, designed by M. Bertin, will soon be commenced at Rochefort. The length is 425 feet and the displacement 7,700 tons. The machinery will consist of three triple-expansion engines driving three screws, developing about 17,000 I.H.P., and giving a speed of 21 knots. The arrangement of armor is similar to that of the *Amiral de Gueydon*, but thinner. It will extend to a height of 10 feet above the water line at the bow, which will be reduced to about 3 feet at the after end of the belt. It will extend uniformly to a depth of about 4 feet below the water line. The thickness will vary from 4 inches to 3.4 inches at the upper edge, and will be 1.5 inches at the lower edge. The protective deck will be 2 inches thick on the sides and 0.9 inch on the flat; this is in addition to the plating, two strakes of 0.4 inch each.

The battery consists of ten 6.5-inch rapid fire guns, with an initial velocity of 2,870 foot-seconds. Two of these will be mounted in turrets at the bow and stern, the other eight being in an armored redoubt, but so arranged as to give a considerable range of fire ahead and astern. Each gun is really in a casemate, with 4-inch armor on the side and 2-inch division bulkheads. The top and bottom of these casemates are nearly an inch thick.

Lavoisier.—A full-power trial under natural draft occurred March 30 and 31, lasting 24 hours, when a mean speed of 18.6 knots was obtained with a development of 4,560 I.H.P. The coal per I.H.P. was 1.65 pounds. "Le Yacht," in commenting on this trial, says: "This twenty-four-hours' trial is decisive and demonstrates the endurance of the vessel at high speeds for long distances. The *Lavoisier* is a good example of the importance of not skimping displacement and dimensions if a good ship of a given type is to be obtained. The *Lavoisier* is an enlarged *Troude*, and the enlargement has enabled the building of a faster

and stauncher vessel and one which is better able to maintain its speed. It has also permitted an increase of the battery by two 4-inch rapid-fire guns; and to protect them, as well as four 5.5-inch rapid-fire guns, by steel shields 2 inches thick, while the main battery of the *Troude* has no protection. The only mistake is in not increasing the bunker capacity. On her full-power trial, a speed of 21.5 knots was obtained with 7,450 I.H.P. The contract required 20 knots and 6,400 I.H.P. Her length is 330 feet and the displacement 2,317 tons.

D'Assas.—[Already described in the JOURNAL, Vols. VI and VIII.]—The full power trial was conducted February 14 in the Bay of Douarnenez under very favorable conditions except a long swell for part of the course, and was entirely successful. The contract required the development of 9,300 I.H.P. without exceeding 145 revolutions and without burning more than 32.5 pounds of coal per square foot of grate. The penalty was 200 francs per each I.H.P. short of the requirement, and there was also a penalty for excess of coal. If the I.H.P. fell below 8,800 or the coal exceeded 34.5 pounds per square foot of grate, the ship would be rejected. The actual results of the trial, which lasted four hours, were as follows: 9,500 I.H.P., 144 revolutions, and 24.2 pounds of coal per square foot of grate. Notwithstanding the swell, the average speed was 19.8 knots. The whole of the machinery worked satisfactorily.

On March 1, there was a coal-consumption trial at 1,000 I.H.P. The speed was between 9 and 10 knots, and the coal worked out at 1.68 pounds per I.H.P. per hour, the contract requiring it not to exceed 1.86 pounds. A second economy trial, at 3,500 I.H.P., took place March 5; fourteen boilers out of twenty were in use. The speed, as determined by several runs over the measured base in the Bay of Douarnenez, was 16 knots, which is considered remarkable for the power developed. The coal per I.H.P. was 1.52 pounds. The limits were 1.65 and 1.75, with a premium for results lower than the former and a penalty if the latter were exceeded. The third economy trial, at 8,000 I.H.P., occurred March 12, lasting like the others, six hours. The mean speed was 18.7 knots and the coal per I.H.P., 1.82. All of the twenty boilers were in use but with natural draft only.

Masséna.—[Already described in the JOURNAL, Vols. IV and VII.]—A contractor's preliminary trial of the *Masséna* (triple-screw battleship) was run under the most favorable conditions in the Bay of Douarnenez near Brest on the 9th of February, when a speed of 16.97 knots and 13,850 I.H.P. were obtained. The revolutions were 125.3, and the coal per square foot of grate, 24.5 pounds. The speed required by the contract is 17 knots. It is the intention, before running the official trial, to modify the thrust bearings, which have given some trouble by heating.

Suchet.—This vessel is an enlargement of the *Davout*, although originally designed as a sister ship. During the construction of the *Davout*, it was found that she would be crowded for room, and the work on the *Suchet* was temporarily suspended. The machinery of the *Davout* was so badly cramped that it was difficult to get around in the compartments. Without mentioning other features, it may be said that it was decided to lengthen the *Suchet* by 23 feet amidships, and the benefit derived has been considerable. The principal items of improvement are: the addition of two cylindrical boilers for auxiliary purposes in port, which also serve to reduce the rate of combustion at full power; a decided improvement in the ventilation of the machinery spaces; an addition of four 4-inch rapid-fire guns. Of the increased length, 7.5 feet were put in the machinery compartments, greatly increasing the accessibility.

On trial, the speed of the *Suchet* was not much greater than that of the *Davout*, but it was more easily obtained and the trials were not so hard. The maximum speed of the *Suchet* was 20.41 knots; that of the *Davout*, 20.07. On the twenty-four-hour natural-draft trials, they both made 16.7 knots.

The following table gives the dimensions of the two vessels:

	Davout.	*Suchet.*
Length, feet,	289	322
Beam, feet,	39.6	39.7
Displacement, tons,	2,991	3,430
Battery,	VI, 6.5-in.	VI, 6.5-in.
	IV, 2.6-in.	IV, 4-in.
	IV, 47-mm.	VIII, 47-mm.
	VIII, 37-mm.	VIII, 37-mm.

The *Suchet* is also the only French vessel having a bow torpedo tube below water.

Catinat.—According to "Le Yacht," this vessel recently completed its series of trials by one of twenty-four hours to determine the coal consumption. The weather was fine and the trial made under excellent conditions. The horse power developed as an average for the twenty-four hours was 6,455 with 115 revolutions of the engines, and the coal consumption was 1.53 pounds per horse power per hour. The mean speed was 17½ knots. A trial was also made of the refrigerating machine intended to prevent the elevation of temperature in the powder magazines. This trial was also successful. According to the journal already cited, the coal capacity of this vessel is 700 tons, which would give a radius of action of seven days at 17½ knots, assuming that the personnel could provide the coal rapidly enough during this length of time. The full-power trials of the *Catinat* were held shortly before the coal-consumption trial just mentioned. The contract required an average horse power of 9,000 for four hours with a mean speed of 19 knots. The actual results on trial were 9,938 horse power with the engines making 132.5 revolutions. The mean speed over a measured base was 19.62 knots. The coal consumption was 1.75 pounds per horse power per hour, and the amount burned per square foot of grate, 23.8 pounds. "Le Yacht" compares the trial of the *Catinat* with that of the *Descartes*, which is a similar vessel, and says that this latter obtained a speed of 19.66 knots with 8,800 horse power, although the displacement was only 77 tons less than that of the *Catinat*.

Charlemagne.—The contractors, MM. Schneider & Co. of Creusot, have recently conducted preliminary trials under natural draft with excellent results. A mean speed of 14.3 knots with 95 revolutions and 5,400 I.H.P. was easily obtained, the coal per I.H.P. being 1.56 pounds. The full-power natural-draft trial gave 16.5 knots for 9,000 I.H.P., so that it is considered comparatively easy to maintain this speed steadily for a number of days. It is expected that the forced-draft maximum trial will

give 14,500 I.H.P. and 18.5 knots. The displacement of the *Charlemagne* is 11,275 tons.

The new type Belleville boilers with economizers are fitted on this vessel, like those of the *Diadem* described elsewhere in this number.

The lines of the vessel are excellent, as at 17 knots, the bow wave was very slight, and not enough to affect the speed, thus differing from some other ships, like the *Massêna*, for example. The other vessels of this class are the *Gaulois* and the *St. Louis*, and all three are expected to be in service by 1899. During the turning trials, a circle of about 2,000 feet diameter was obtained with a helm angle of 5 degrees.

Châteaurenault.—The launch of this triple-screw commerce-destroyer was expected on March 24, but has been delayed by a strike. She has very fine lines, as is evident by inspection as she rests on the ways. The three screws are in place. The blades are short but wide. The stem is almost straight, with a slight tendency to the "swan-neck." The stern is long and like that of a merchant steamer. Length, 442 feet; beam, 55.6 feet; draught, 24.3 feet; displacement, 8,000 tons. The engines are of 23,000 I.H.P., supplied by Normand boilers. The bunkers can be stowed with 1,400 tons of ordinary coal, but an amount greater by one-third can be carried if briquettes, carefully stowed, are used. An even greater amount can be carried if all available spaces are used. The maximum speed with forced draft is 23 knots, and with natural draft, 22 knots. A radius of action of 7,500 knots at 12 knots' speed is anticipated.

GERMANY.

Second-Class Cruiser (not yet named).—This vessel is building at Dantzig and was recently launched. The dimensions are as follows: length between perpendiculars, 345 feet; beam, 56.8 feet; mean draught, 20.7 feet; displacement, 5,900 tons. There is a partial armor belt, 230 feet long, 2.5 inches thick and 8 feet wide, with wood backing. The protective deck varies from 1.6 inches to 4 inches in thickness, descends to 5 feet below the water-line at the sides, and is 1.6 feet above the water-line amidships.

There are three triple-expansion engines of the four cylinder, vertical type, driving three screws, and supplied with steam from water-tube boilers. The expected I.H.P. is 10,000 under forced draft, giving a speed of 20 knots. The normal coal supply is 500 tons, and the total bunker capacity, 950 tons. There is also provision for using liquid fuel.

Gunboats.—Schichau has just begun work on two gunboats to be delivered about the end of this year. Length, 202 feet; beam, 30 feet; mean draught, 10.6 feet; displacement, 895 tons. They are to have twin-screw engines of 1,330 I.H.P., and a speed of 13.5 knots. The coal supply is 120 tons. The battery consists of four 3.5-inch rapid-fire guns, and six mitrailleuses.

Torpedo Boats.—Schichau is also building six 30-knot torpedo boats. Length, 158 feet; beam, 16.7 feet; mean draught, 8.2 feet; displacement, 155 tons. The battery consists of one 5 c.m. rapid fire gun and one mitrailleuse. The fuel supply will be 30 tons of coal and 7 tons of fuel oil.

Destroyer.—The successful launch of a new type of division boat, under construction by Messrs. Thornycroft & Co. for the German Navy, took place on the 16th of March, at Chiswick. The vessel is 211 feet 9 inches long, and has engines of about 6,000 I.H.P., and Thornycroft water-tube boilers. She is armed with five 5 c.m. guns and three torpedo tubes. The guaranteed speed is 27½ knots carrying a load of 84 tons.

JAPAN.

Asama.—The armored cruiser *Asama*, built at the Elswick Yard to the order of the Japanese Government, was launched on the 22d March. The new cruiser is 408 feet in length between perpendiculars; her moulded breadth is 67 feet; her depth is 41 feet; her mean draught, 24 feet 3 inches; her displacement will be 9,750 tons, and her coal capacity 1,300 tons.

As regards her armament, she carries, in addition to machine guns and the like, four 8-inch guns in twin armored barbettes and gun houses. She carries also fourteen 6-inch guns, ten with 6-inch nickel-steel casemates, and four with 6-inch shields; and she carries, further, twelve 12-pounders and seven 3-pounders. She has also five torpedo tubes, four of them being submerged.

It may be convenient also to specify the nature of her forward and broadside firing capacity, each of which is very strong. Her forward firing capacity includes two 8-inch guns, four 6-inch guns, and two 12-pounders, besides minor guns. Her broadside fire will include four 8-inch guns and seven 6-inch guns. These quick-firing guns, capable of discharging four rounds in a minute, have, it should be added, a muzzle velocity of 2,650 foot-seconds. The Elswick authorities have demonstrated by experiment that there is no difficulty in attaining a velocity of 2,950 foot-seconds from either 6-inch or 8-inch guns. Such is the armament of a vessel designed for warlike purposes, of which the contract speed is 21¼ knots, but from which 21½ knots is expected with confidence. There are also noteworthy points in her armor. Her transverse bulkheads are of 6-inch Harveyized steel, and her wings and casemates are nickel steel. She has a complete 7-inch belt of Harveyized steel, which is at least equal for defensive purposes to a 10-inch plate of ordinary armor. This Harveyized steel has come from Messrs. Cammell, of Sheffield, exclusively.

Shipbuilding for Japan.—For the past two years or so, attention has been drawn to the number of ships which were being built in various countries for Japan. A Japanese journal prints the following lists, giving particulars of those at present under construction.

ENGLAND.—*Three ironclad battleships.*

Name	*Shikishima*	*Asashi*	Not yet named
Builders	Thames Iron Works	Thompson & Co.	Armstrong & Co.
Length	438 ft.	425 ft.	440 ft.
Beam	75 ft. 6 in.	75 ft.	76 ft. 6 in.
Draught (average)	27 ft. 3 in.	27 ft. 3 in.	27 ft.
Displacement	15,188 tons	15,400 tons	15,140 tons
Speed	18 knots	18 knots	18 knots
Date of completion	May 4, 1899	October 5, 1899	March 24, 1900

Three armored first-class cruisers.

Name	*Asama*	*Tokiwa*	Not yet named
Builders	Armstrong & Co.	Armstrong & Co.	Armstrong & Co.
Length	441 ft.	441 ft.	439 ft.
Beam	67 ft. 1 in.	67 ft. 1 in.	68 ft. 6 in.
Draught (average)	24 ft. 4 in.	24 ft. 4 in.	24 ft. 3 in.
Displacement	9,855 tons	9,855 tons	9,906 tons
Speed	21½ knots	21½ knots	20¾ knots
Date of completion	Sometime, 1898	Sometime, 1898	Dec. 25, 1899

One armored second-class cruiser.

Name,	*Takasako*
Builders,	Armstrong Co.
Length, feet,	380
Beam, feet,	46
Draught (average), feet,	19
Displacement, tons,	4,227
Speed, knots,	22½
Date of completion,	Sometime 1898.

Besides the above-mentioned, eight torpedo-boat catchers (of 31 knots and 316 tons displacement each) are ordered from England.

FRANCE.—*One armored first-class cruiser.*

Name,	*Azuma*
Builders,	Roitol (?)
Length, feet,	452
Beam, feet,	59
Draught (average), feet and inches,	23–8
Displacement, tons,	9,460
Speed, knots,	20
Date of completion,	June, 1900

GERMANY.—*One armored first-class cruiser.*

Name,	*Yakumo*
Builders,	Vulcan Company
Length, feet,	435
Beam, feet,	65
Draught (average), feet and inches,	23–3
Displacement, tons,	9,800
Speed, knots,	20
Date of completion,	April, 1900

AMERICA.—*Two armored second-class cruisers.*

Name,	*Kasagi*	*Chitose*
Builders,	Cramp, Philadelphia	Union Iron Works, (San Francisco)
Length, feet,	400	405
Beam, feet and inches,	48–9	49
Draught (average), feet and inches,	17–9	17–7
Displacement, tons,	4,980	4,840
Speed, knots,	22½	22½
Date of completion,	December, 1898	December, 1898

RUSSIA.

Khrabri.—On her recent measured-mile trials the *Khrabri*, of 1,492 tons, made an average speed of 14.54 knots as a mean of six runs. The I.H.P. was 2,641, with a steam pressure of 170 pounds, although the Niclausse boilers can carry 200 if desired. The coal consumption was 2.1 pounds per I.H.P., of which 1.65 was for the main engine.

Captain Sacken.—New water-tube boilers to furnish 3,600 I.H.P. have recently been fitted in the torpedo-cruiser *Captain Sacken* of the Black Sea fleet. She has a displacement of 600 tons and is intended to make 18 5 knots. Fans for induced draft have been fitted to the funnels, and the furnaces have been arranged for using liquid fuel.

SPAIN.

Pelayo.—The near approach of war has naturally caused the utmost activity in the Spanish Navy, and the most earnest efforts are being made to get every available vessel into commission with the least possible delay. The ironclad *Pelayo*, at the time the Cuban question reached an acute stage, was in dock at Toulon, where she was being refitted with a new boiler installation, Niclausse boilers being substituted for those already in the ship. In such a crisis, no attempt could be made to carry out complete trials, and a full-power trip was the most that could be done, but the conditions under which it was made, and the re-

sults given by the new boilers, seem sufficiently remarkable to merit notice.

The pipe work was not completed till the evening of April 6, and up to that time it had only been possible to raise steam in two out of the sixteen boilers. Owing to the want of steam pipes the remaining fourteen had never even had a fire below them. There was no time to try them, however, and early on the morning of April 7 the *Pelayo* sailed with all her boilers under steam. In two hours after leaving she attained her full speed of 16 knots with natural draft, all boilers being at work, and she maintained this speed during four hours. The horse power developed was 8,000. The boilers throughout worked satisfactorily, and the pressure was maintained with ease, although the stokers were exclusively Spanish merchant sailors, mobilized in readiness for war, who for the most part had no knowledge of boilers; the complement also was very incomplete.

The results were so satisfactory that the Spanish Commissioners decided to accept the machinery at once, and toward four o'clock in the afternoon the *Pelayo* continued her voyage to Carthegena, after landing the contractor's representatives.

The Niclausse boiler is in use on several other Spanish war vessels, among which may be mentioned the cruiser *Cristobal Colon*, of 14,000 horse power, and on many ships of the French and other Navies. The run above described well maintains the reputation of its previous performances, the most striking of which was the recent test of the French cruiser *Friant*, under what were intended to be actual service conditions. It will doubtless be remembered that she was suddenly ordered to leave Quiberon, run to Cape Finisterre at 17 knots, then cruise in the Atlantic for six days and nights at 16 knots, watching for an imaginary enemy, and finally return to Quiberon at 17 knots. This she successfully accomplished without any special preparation. The present performance is, perhaps, even more remarkable, seeing that only two of the boilers had been under steam before; and it speaks well for the quality of material and accuracy of workmanship employed, that the whole sixteen worked without hitch at full load from the moment of first lighting the fires under them; while

the ease with which the pressure was maintained, in spite of the utter inexperience of the stokers, is conclusive evidence of the steaming powers of these boilers.

The following is a brief description of the boiler installation on the *Pelayo*, with leading particulars and dimensions: There are sixteen boilers in all, divided into four similar groups, two forward and two aft. The two forward groups are separated from each other by a longitudinal water-tight bulkhead; and the after groups are divided in the same way. Each group thus consists of four boilers, which are arranged in pairs; the two pairs are placed back to back with no space between, and the fronts run athwartship. This arrangement, which is only possible with boilers permitting all operations, whether of working or overhauling, to be performed from the front, is very economical of space.

It will be seen from the above that each group has two stokeholds, each stokehold serving for two boilers. These stokeholds are very large, because the length of the Niclausse boilers is much less than that of the old cylindrical boilers. Thus the forward and after stokeholds of the two after groups are 20 feet and 8 feet 8 inches wide, respectively, and are of the full half-width of the ship; there is a passage from the forward to the aft stokehold in each group, 2 feet 2 inches wide, between the boilers and the side. The forward and after stokeholds of the two forward groups are 20 feet 9 inches and 8 feet wide, respectively. It is evident that a portion of these spaces is available as auxiliary store-rooms, etc., since a width of 7 feet 10 inches is sufficient for the withdrawal of the tubes and other operations. There are two funnels, one for each pair of groups. Each boiler consists of 15 headers, each containing 18 tubes. The tubes are of steel, all lap-welded, except those of the lower rows, which are weldless; their external diameter is 3.2 inches, and their thickness .137 inch; they slope to the rear at an inclination of 1 in 10, and are fixed in the headers by metallic-coned joints, like all boilers of the Niclausse manufacture.

The steam and water drums are 9 feet long and 2 feet 8 inches in diameter, and the headers are attached to them by the ordin-

ary double cone joints. On the top of each drum is a small steam drum, 11¾ inches high, in which is the intake of the steam pipe. The other end of this pipe is connected to the steam outlet on the drum which supplies the steam pipes both for the main engines and the auxiliary machinery. Within the drums are placed the mud catchers, the guide pipes for the descent of water into, and ascent of steam from each header, two feed pipes, and the cock to which the steam jet used in cleaning the outside of the tubes is connected. On the outside of the drums are the safety valves, the "Soupape avertisseuse," water-gauge fittings, pressure gauge, two feed valves—one to the pump on the main engine, the other to the auxiliary pumps—a blow-off cock, a "robinet de plein," and an automatic feed regulator. The bottoms of the headers of each boiler are connected by a pipe with a blow-off cock discharging into the main blow-off. Each boiler has three fire doors, three ashpit doors, and two main doors in the front of the headers. For the safety of the stokers, in case of a tube bursting, the fire and ashpit doors open inwards, and consequently close automatically under internal pressure; the fire doors are also balanced.

The following are the principal particulars and dimensions of the installation:

	Per boiler.	Total.
Number of boilers	.....	16
Number of furnaces	1	16
Number of headers	15	240
Number of outer tubes	270	4,320
Number of inner tubes	270	4,320
Diameter of outer tubes, inches	.....	3.22
Diameter of inner tubes, inches	.....	1.57
Length of outer tubes, feet and inches	.....	7–1
Length of inner tubes, feet and inches	.....	6–11
Grate area, square feet	53.25	852
Heating surface, square feet	1,760	28,160
Heating surface ÷ grate area	32	
Floor space occupied, square feet	76.25	1,220
Grate area per square foot floor space, square feet	.7	
Heating surface per square foot floor space, square feet	23	
Horse power	8,500	
Water space, cubic feet	120	1,920
Steam space, cubic feet	25.4	4,064

	Per boiler.	Total.
Number of fire doors	3	48
Number of ashpit doors	3	48
Number of funnels	.....	2
Pressure, pounds per square inch	170	
Weight of boilers, including framework setting, valves and cocks, tubes and headers and drums, tons	255	
Weight per square foot of heating surface, pounds	20	
Weight per square foot of grate area, pounds	620	
Weight of boilers as above, including water and all accessories, tons	345	
Weight per square foot of heating surface, pounds	27.4	
Weight per square foot of grate area, pounds	900	

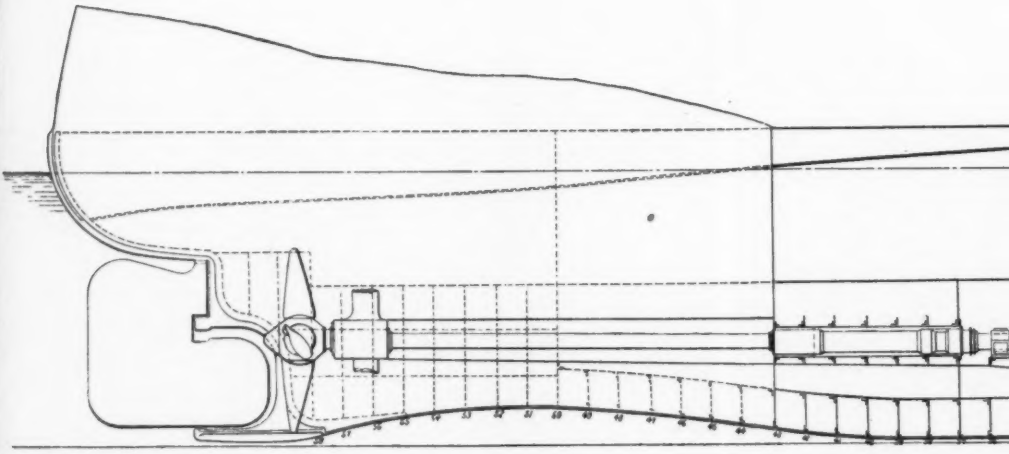
—"Engineering."

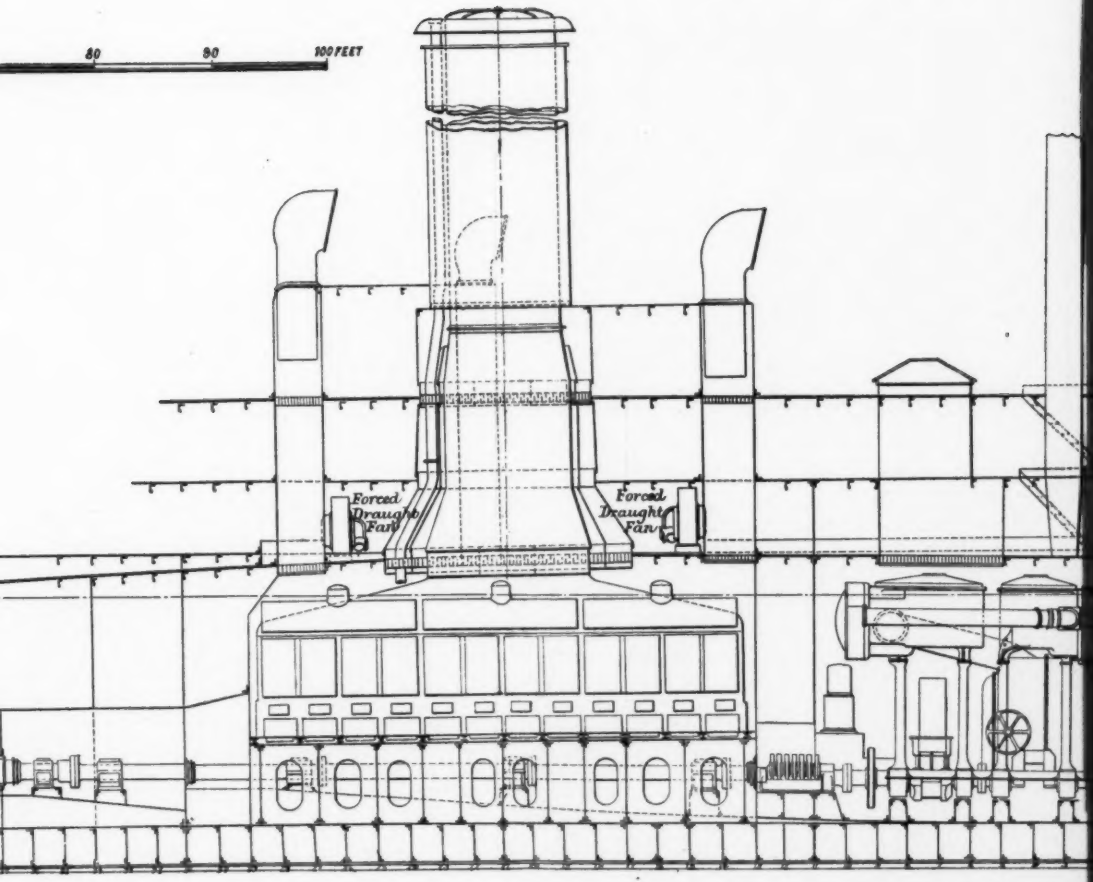
Cristobal Colon.—[An extended description of this vessel has already been given on page 614, Volume IX.]—Spain has recently added to her fleet of war vessels a cruiser that would, without doubt, play a very important part should any question arise with the United States that caused an open rupture; and, indeed, it was the delicate relations with that power, consequent upon Cuban difficulties, that caused the purchase of the vessel in the first instance.

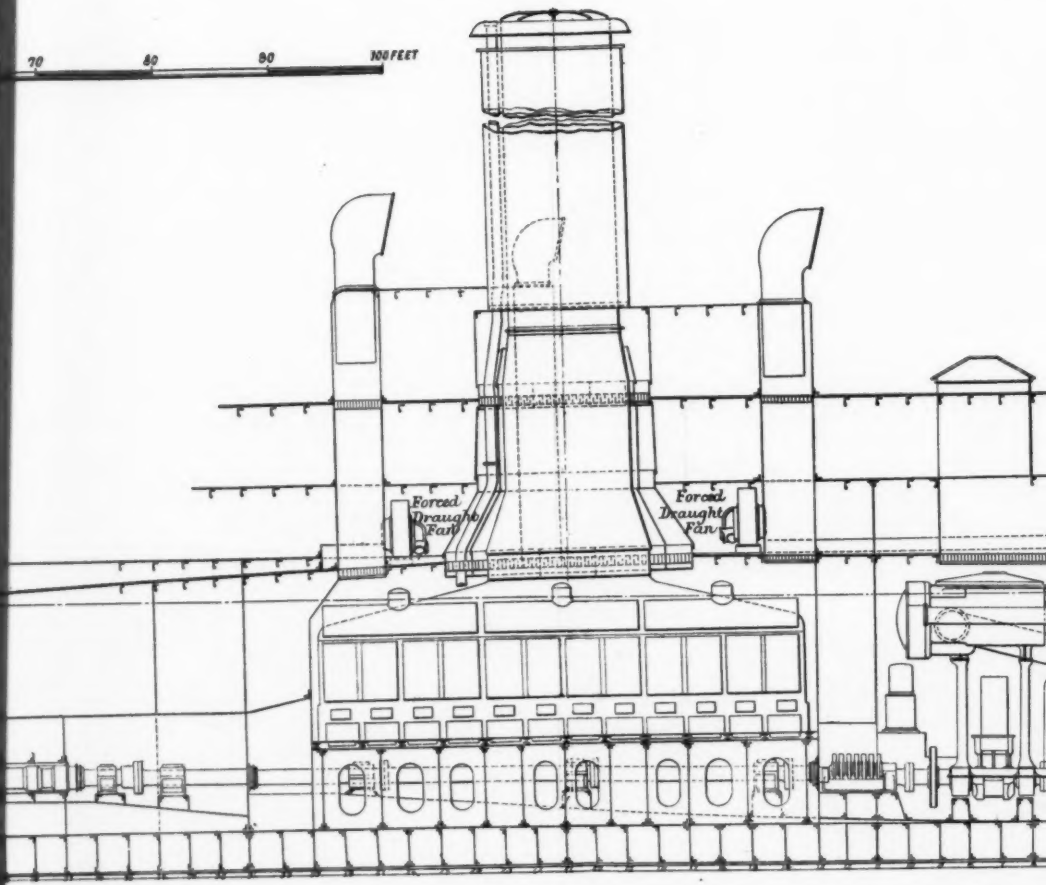
It will be remembered that one of the six vessels in the last Italian naval programme (which dates so far back as 1891) was named the *Guiseppe Garibaldi.* She was to be built and engined complete by Messrs. Ansaldo & Co., of Sestri Ponente and Sampierdarena, near Genoa, and she was to be delivered within six years. But the capacity of the Ansaldo's works is such that the construction of the engines was completed, and the ship ready for launching within twenty-two months.

It was just at this time that the Argentine Republic, having one of those perennial differences of opinion with its sister Republic of Chili, was looking about for warships to add to its fleet as an answer to the threatening armament that Chili was gradually accumulating, and overtures were made to the Italian Government for the purchase of the *Guiseppe Garibaldi.* It was then arranged that Messrs. Ansaldo should have power to dispose of the vessel to Argentina on the condition that the second one should be delivered to the Italian Government within the time originally stipulated for the first one; and with the further pro-

Fig. 2.




60
80
100 FEET
Forced Draught Fan
Forced Draught Fan


70
80
90
100 FEET
Forced Draught Fan
Forced Draught Fan

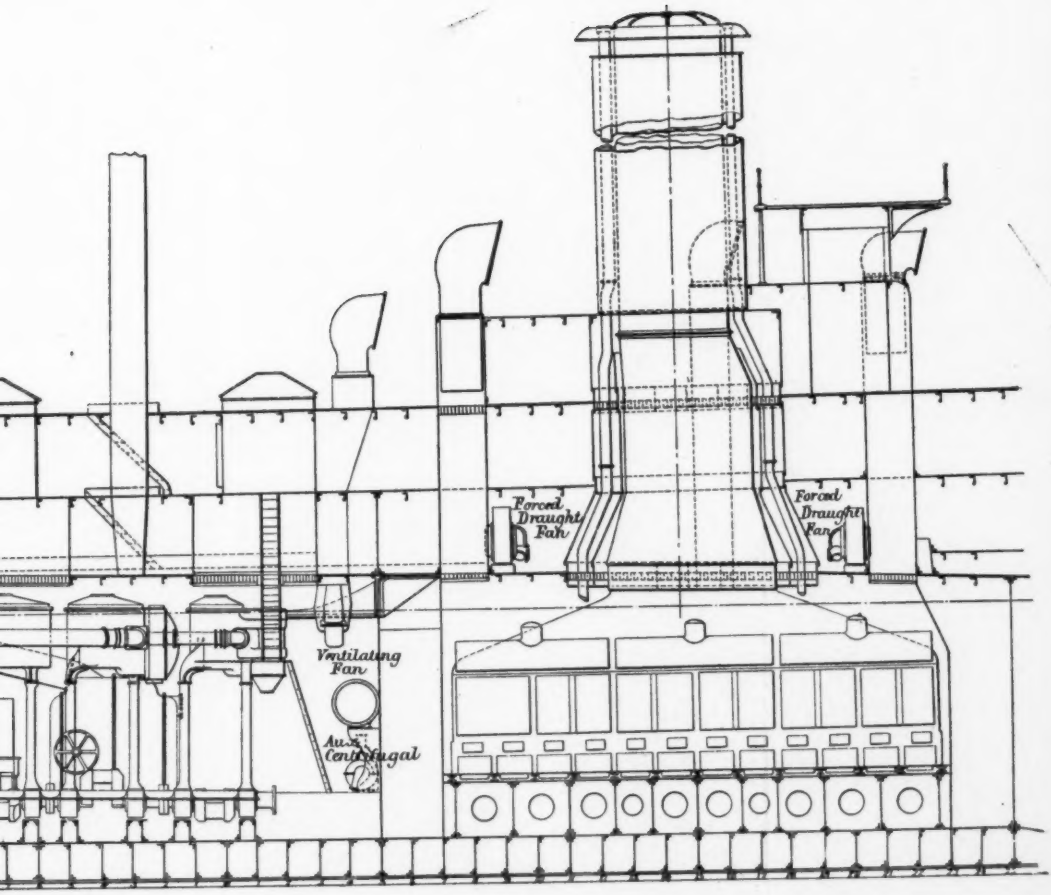
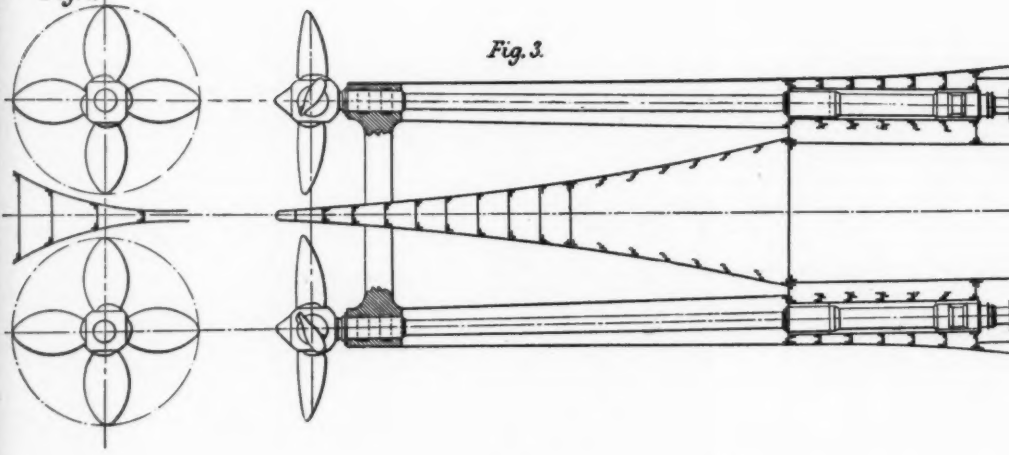
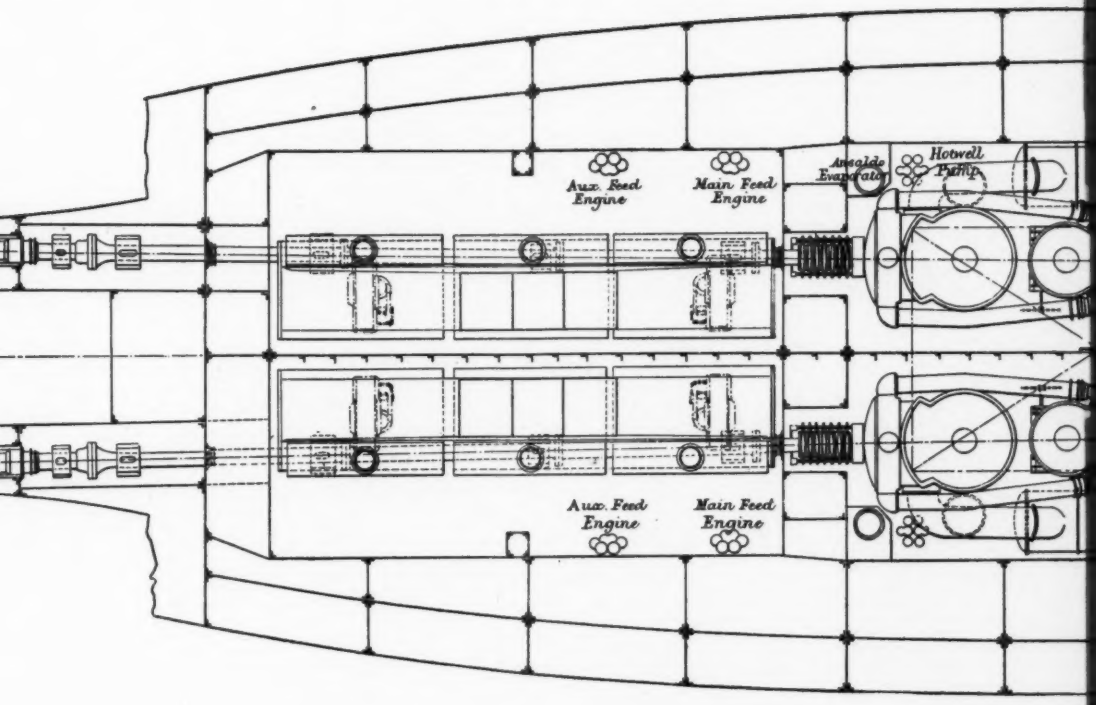
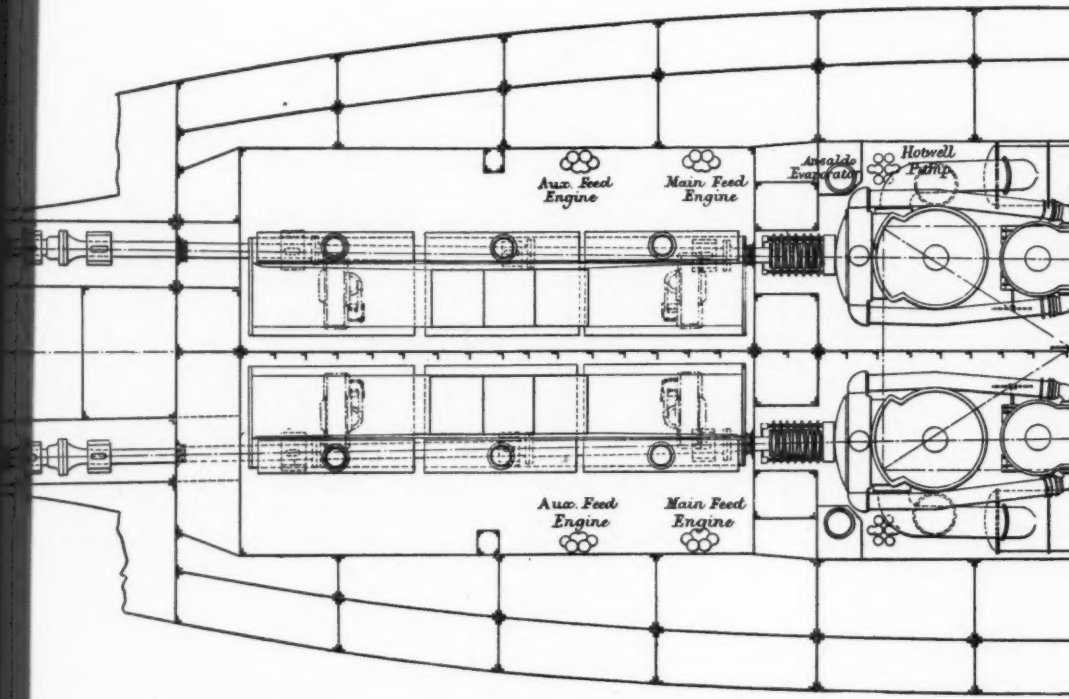

Forced Draught Fan
Forced Draught Fan
Ventilating Fan
Aux. Centrifugal

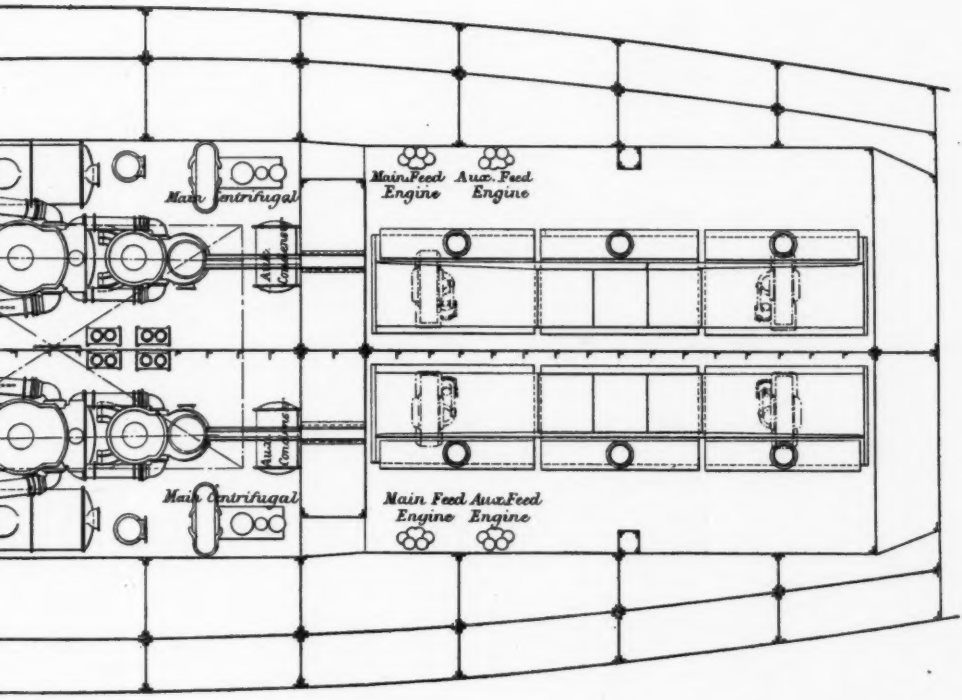
Fig. 4.

Fig. 3.




Aux. Feed Engine
Main Feed Engine
Ansaldo Evaporator
Hotwell Pump
Aux. Feed Engine
Main Feed Engine


Aux. Feed Engine
Main Feed Engine
Hotwell Pump
Aux. Feed Engine
Main Feed Engine


Main Feed Engine
Aux. Feed Engine
Main Centrifugal
Aux. Condenser
Aux. Condenser
Main Centrifugal
Main Feed Engine
Aux. Feed Engine

viso that, in consideration of the granting of such a favor, Messrs. Ansaldo were to fit the new vessel with water-tube boilers, in place of the cylindrical ones provided for the original vessel, and that all material for the new ship should be obtained in the Kingdom of Italy as far as possible.

The name *Garibaldi* was retained for the Argentine vessel, in recognition of all that that hero did for Argentina, and the vessel was speedily completed and handed over to the Argentine authorities. The fitting of the machinery on board was a remarkably smart piece of work for any country, the engines and boilers being ready for their steam trials ten weeks after the vessel was launched. The keel of the second ship was laid on September 25, 1895, and her construction so pushed forward that there was every probability that she also would be ready for sea long before the time originally stipulated. It was at this juncture that Spain, seeing the urgent necessity of adding to her fleet some modern and really serviceable vessels, decided to purchase the *Garibaldi No. 2* if it were possible, and the Italian Government was again approached with a request for the cession of the second vessel. This was again granted on the same terms as before, but with a distinct warning from the Italian Ministry of Marine that on no account would any extension of time for final delivery be granted, and any fines for delay would be most strictly enforced.

The launch of this second vessel took place on September 16, 1896, and was made the occasion of a most remarkable outburst of enthusiasm and scene of fraternization between the Spanish and Italian peoples. A large steamer was chartered and sent to Barcelona for representatives of all the principal Spanish newspapers, and these journalists had public receptions and festivities in their honor wherever they went. The vessel left the ways in the presence of cheering thousands, and was named *Cristobal Colon* by Madame Benomar, the wife of the Spanish Ambassador to the Court of Italy.

The leading dimensions of the vessel are as follow: Length, 328 feet; beam, 59 feet 9 inches; and draught, 23 feet 3 inches, at which the displacement is 6,840 tons.

The armament consists of two 9.8-inch guns placed at either end of the vessel en barbette, ten 6-inch, six 4.7-inch, ten 57-1 illimeter, and ten 37-millimeter guns, all, with the exception of the two large guns, being quick firing. There are also two machine guns and two light guns with their carriages for use on shore.

The propelling machinery (see the two large plates) consists of two sets of triple-expansion inverted engines having cylinders 42 inches, 63 inches and 93 inches in diameter, respectively, with a stroke of 3 feet 10 inches. Each cylinder is supported by four cast-steel columns with cast-iron crosshead guides bolted on their faces and standing on cast-steel main bearing frames. The high-pressure cylinders are fitted with piston valves, while the intermediate and low-pressure cylinders have double-ported slide valves, all being worked by double eccentrics and Stephenson's link motion. The piston-rods, connecting-rods and shafts are of steel, these latter being hollow throughout, and the crankshaft being made in three parts, which are interchangeable. The condensers, two in number, are of Delta metal, and are fitted with horizontal tubes through which the water passes, and have a cooling surface of 14,600 square feet. There are two single-acting air-pumps made of gun metal 33 inches in diameter and 21 inches stroke, worked by beams from the low-pressure cylinder crossheads. There are two large centrifugal pumps, each worked by a compound engine, and each is fitted with a small auxiliary single-acting air pump for the purpose of maintaining a vacuum, and keeping the main condensers free of water when the main engines are stopped. An auxiliary condenser is fitted in each engine room, having its special circulating and air pump.

Messrs. Maudslay's latest arrangement with secondary tanks for maintaining a constant head of water against the suction valves of the feed-pumps was adopted, and was found to give admirable results on the trials. The main air-pump, the auxiliary pump on the main centrifugal-engines, and the air-pump of the auxiliary condenser, all deliver into a tank *A* (Figs. 5 and 6); from this the water is lifted by a special pump with two cylinders, *B*, into a second tank, *C*, called the feed tank, placed as high up as possible under the steel deck. In this case part of

Fig. 5.

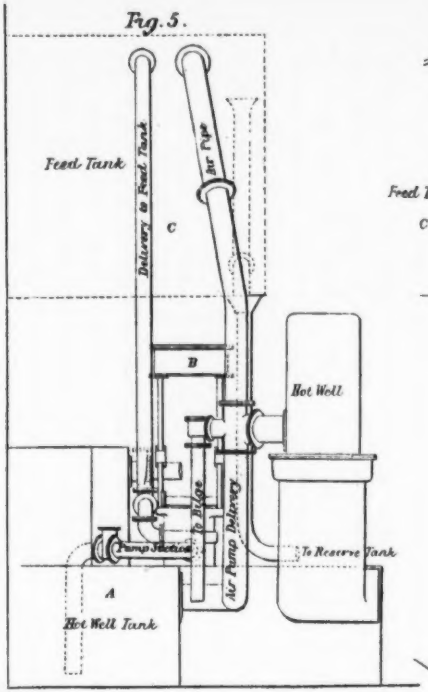
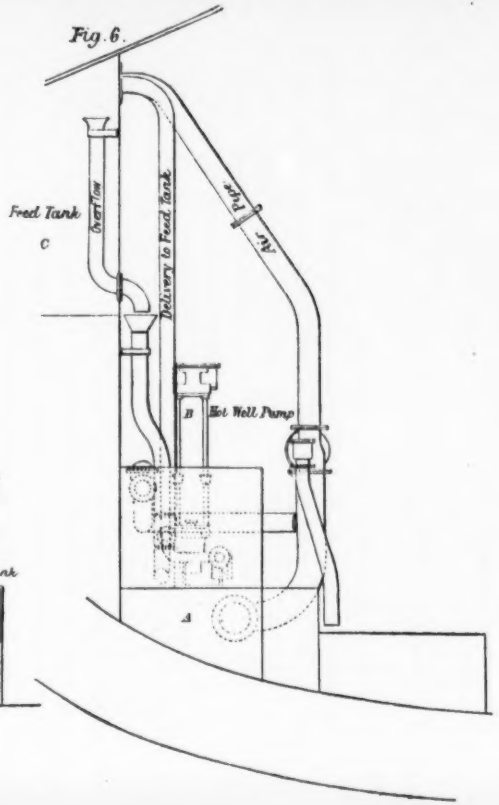

Feed Tank
Delivery to Feed Tank
Air Pipe
C
B
Hot Well
To Reserve Tank
Air Pump Delivery
A
Hot Well Tank

Fig. 6.


Feed Tank
C
Overflow
Delivery to Feed Tank
Air Pipe
B
Hot Well Pump
A

the wing compartments at the after end of the engine rooms has been adapted for the purpose. The working of the pump is regulated by a float in the hotwell tank, so that it is as regular as possible. From the feed-tank are led the various suctions to the feed engines, which are of the duplex type, two being placed in each boiler compartment. In practice, this arrangement has been found to have several advantages, amongst them being the very regular working of the hotwell-pumps, as they have only to lift the water a short distance and not against pressure; and also that, as the feed-tank is placed at a good height, so that there is always a head of water against the suction valves, no air gets into the valve or pump chambers of the feed-pumps, and they deliver almost the theoretical quantity of water due to each stroke. Even at full power the speed of the feed-pumps never attained 25 strokes per minute, whilst on the *Garibaldi No. 1*, identically the same pump to do the same work required over double the number of strokes when running at full power.

The steam producing apparatus consists of twelve water-tube boilers of the Niclausse type, which were made in Paris. The boilers are placed back to back against the central bulkhead, three in each compartment, and á funnel is provided for each group of six boilers.

The vessel was ready for trial in March, 1897, the official natural-draft trial taking place on April 29, 1897, when the results exceeded every expectation. The boilers gave such an ample supply of steam that the full contract speed of the vessel was obtained without even putting the fans in motion, the mean results of the three-hour trial being as follows:

	Starboard.	*Port.*
Pressure of steam at engines, pounds	145	145
Vacuum	28.07	28.4
Revolutions	98.4	98.4
Mean pressure, high-pressure cylinder, pounds	58.12	55.96
Mean pressure, intermediate pressure cylinder, pounds	24.41	24.99
Mean pressure, low-pressure cylinder, pounds	12.21	11.81
Indicated horse power	5,363	5,308
Collective indicated horse power	10,671	
Contract indicated horse power	8,600	

As is usual on trials with ships fitted with water-tube boilers, the firing was done regularly, each furnace being charged with a certain amount of fuel at stated intervals, a clock being fitted in each stokehold to facilitate this.

The mean speed on this trial, on a long base, was 19.35 knots, and as this was in excess of the contract speed, the Commission appointed by the Spanish Government to receive the vessel, decided that no further full-speed trial was necessary.

Besides the substitution of water-tube boilers and the application of hot-well pumps with their tanks and service of pipes, the second vessel possesses many other improvements, which were found desirable or necessary from experience with the first *Garibaldi*.

The principal modification amongst these is in the disposition of the 6-inch quick-firing guns at the forward end and at the after end of the main battery so as to give an increased range for these guns. This is such that not only is there an increased total range of 10 degrees, but also these guns can be fired in a fore-and-aft direction on a line almost parallel with the keel.

The steam hoists for ammunition have been superseded by others of greater capacity, having electricity as their motive power, hand gear also being fitted. The electric gear for training and loading the 9.8-inch guns has been much improved, and also the electric firing gear for the smaller guns.

As the result of all this extension of the uses of electricity on board, the quantity of electric energy generated has been augmented by 50 per cent., and four large dynamos are now fitted forward and two aft. The electric search lights have been fitted with electric gear for maneuvering them from a distant point of observation. This will be a great advantage in the case of night attacks by torpedo boats, and indeed on all occasions when it is necessary to use them.

Of course, the forward underwater launching-tube for torpedoes has been abandoned, after the result of the experiments made in England, and amongst other improvements may be noted that the protection of the 6-inch quick-firing guns has been increased, and three more boats are carried. As the consequence of the

altered position of the boilers, the stability of the vessel is improved and a steadier gun platform thereby obtained.

Incidentally, the building of the *Garibaldis* and their sister vessels gives a good example of the rate of construction in the yards of Messrs. Ansaldo compared with the Government dockyards and with other private shipyards, and the table below will show how very far advanced they are in comparison to all other establishment in Italy.

DATES OF LAYING DOWN AND LAUNCHING SOME ITALIAN WARSHIPS.

—	*Carlo Alberto.*	*Garibaldi (No. 1).*	*St. Martin.*	*Cristobal Colon (No. 2).*	*Guiseppe Garibaldi (No. 3).*
Constructor	Government Dockyard	Ansaldo	Orlando	Ansaldo	Ansaldo
Place of construction,	Spezia	Sestri Ponente	Leghorn	Sestri Ponente	Sestri Ponente
Keel laid	Feb. 17, 1893	July 25, 1893	Nov. 23, 1893	Sept. 25, 1895	Oct. 5. 1896
Launched	Sept. 13, 1896	June 27, 1895	May 25, 1897	Sept. 16, 1896	Sept. 20, 1897.
Steamed at moorings	Sept. 13, 1897	Nov. 5, 1895	Sept. 7, 1897	Mar. 15, 1897	Completing
Full-power trial	Completing	April 14, 1896	Completing.	April 27, 1897	

The third *Garibaldi* was launched on September 20, 1897, and named *Guiseppe Garibaldi* by Madame Maria Bombrini, the wife of Commendatore Carlo Marcello Bombrini, the head of the firm of Ansaldo, and there is every reason to believe that her completion will be as rapid as that of her sister vessels, and her trials as successful.—"Engineering."

Vitoria.—Les Chantiers de la Seyne (near Toulon) have just completed an extended lot of work on the *Vitoria*, *Numancia* and *Pelayo*, which amounted for the two former to an almost complete rebuilding, while the latter was fitted with water-tube boilers and additional guns made possible by the saving in weight of boilers. The *Vitoria* left la Seyne about March 1st for Carthagena to receive her battery.

The *Vitoria* was built by the Thames Iron Works of London, and launched in 1865, and naturally has become very antiquated, but it happens that her principal defense (complete side armor) is exactly in line with the latest tendency in the armoring of modern ships. Both the *Vitoria* and *Numancia* have side armor varying in thickness from 4.4 to 5.6 inches, but, of course, of iron. The dimensions are: length, 317 feet; beam, 56.8 feet;

draught, 25 feet; displacement, 7,250 tons. The rig has been entirely changed, and now consists simply of two military masts.

There is a single screw driven by a Penn trunk engine, the boilers being of the old rectangular or box type, eight in number. New boilers of the same type have been fitted and the machinery thoroughly overhauled, so that it is now expected that 4,000 I.H.P. can be developed, giving a speed of about 11 knots under favorable conditions.

An entirely new battery has been fitted, consisting of six 16-cm. (6.4-inch) Hontoria guns, two on the bow, two at the stern, and one on each broadside; eight 14-cm. (5.6-inch) rapid-fire guns of the Schneider-Canet type, four on each broadside, with central pivot carriages and shields; six 57-mm. Nordenfeldt rapid-fire guns distributed on each broadside as follows: one on the forecastle, one on the poop and one on a bridge amidships; six Maxims of 37 mm., two in each military top, and two for boat guns.

An electric installation of 28 kilowatts has also been fitted.

"Le Yacht" (to which we are indebted for this description) says: "We think the Spanish government acted wisely in utilizing this hull, by modernizing it as far as possible, as, before the repairs and changes, it was without military value."

UNITED STATES.

Repair Ship.—Among the merchant steamers purchased by the Navy Department is the S. S. *Chatham* of the Merchant and Miners' Line, renamed the *Vulcan*, which is being fitted out with great expedition as a repair ship. As long ago as 1892, when there seemed a prospect of war with Chile, plans were prepared for fitting out several repair ships and work was actually begun on the S. S. *Ohio*.

The *Vulcan* is fitting out at the Boston Navy Yard, under the immediate direction of Chief Engineer Jas. H. Chasmar, U. S. Navy, who has the assistance of Passed Assistant Engineers J. L. Gow (of the regular Navy) and Gardiner C. Sims, W. S. Aldrich and J. Alvah Scott (of the volunteer Navy). It will thus be seen

that the plant is in excellent hands and the best possible results will be obtained from it.

The following list of the tools and outfit is reprinted from a former article in the JOURNAL (p. 72, Vol. VII), and is very nearly accurate for the *Vulcan's* plant. Owing to the necessity for immediate delivery of tools, the sizes in some cases vary slightly from the list.

MACHINIST'S.

1 lathe, gap, 40 inches swing, 20 feet centers.

2 lathes, 30 inches swing, 10 feet centers.

Each of the above to be fitted with boring bar with traveling head.

4 lathes, 18 inches swing, 6 feet centers.

1 lathe, 12 inches swing, 4 feet centers.

1 lathe, monitor, small.

1 planer, to take 4 feet square, 10 feet travel.

2 planers, to take 3 feet square, 5 feet travel.

1 shaper, 24 inches stroke.

1 shaper, 14 inches stroke.

1 shaper, 10 inches stroke.

1 radial-drill, to drill at 48 inches from side of column.

2 drill-presses, 3-inch spindle, to drill up to $1\frac{1}{2}$-inch holes, 12 inches vertical movement.

2 drill-presses, 2-inch spindle, to drill up to 1-inch holes, 12 inches vertical movement.

1 bolt-cutting machine, with standard taps and dies, to cut from $\frac{1}{2}$ inch to 2 inches, varying by $\frac{1}{16}$ inch.

1 pipe-threading machine, to cut from $\frac{1}{2}$ inch to 4 inches, with pipe-taps and dies of standard sizes.

A complete set of cutting tools, dogs, chucks, angle plates, clamps, etc., for each power tool, together with all attachments and fittings complete, including counter shafts, pulleys, etc.

200 feet $2\frac{1}{2}$-inch shafting in 10-feet lengths, with universal couplings and short hangers for each length.

2 driving pulleys of each of the following sizes for power tools, to fit shafting and be ready to be slipped in place thereon: 20, 18, 14 and 12 inches diameter.

75 feet 12-inch double belting.
250 feet 6-inch single belting.
1,300 feet 4-inch single belting.
1,000 feet 3-inch single belting.
12 sides lace leather.
} All to be oak-tanned leather.

1 emery wheel tool-grinder, 18 inches diameter and 2 inches face, fitted complete with all attachments, pulleys, etc.

2 grindstones, coarse, 50 inches diameter and 8 inches face, to run in cast-iron troughs, fitted complete with all attachments, pulleys, etc.

MOULDER'S.

1 36-inch cupola of most improved design, to melt 3,000 pounds metal at each tapping. A blower and engine to furnish blast; hoist, piping and fittings complete.

1 furnace, iron-lined, with fire brick, to take three 100 pound crucibles, funnel about 12 inches diameter.

3 sets crucible tongs, 1 set for each size of crucible.

50 crucibles of 50 pounds capacity.

50 crucibles of 100 pounds capacity.

3 crucible bearers for each size crucible.

3 complete sets of moulder's tools.

COPPERSMITH'S.

1 brazing forge, with two circular and one long fire, for blast, to be built up in light iron and lined with fire brick.

1 set of tools, including shears, stakes, hammers, beck irons, blocks.

3 tinsmith's furnaces, with soldering irons, pots, etc.

BLACKSMITH'S.

1 open-hearth forge, 5 feet in diameter, with cowl and 12-inch funnel, to be built up of brick and iron, used for heavy forging or flange turning, to be fitted for power blast.

2 forges, with power blast, to weld 4 inches square (16 square inches).

2 forges, portable, with hand blowers to weld 2 inches square.

1 Sturtevant pressure blower, to be driven by engine attached; a quantity of 3-inch and 2-inch light iron pipe for leading blasts.

3 portable hand blowers, 14-inch fans, driven by levers.

6 Eagle anvils, with blocks, two of 150 pounds, two of 180 pounds, and two of 200 pounds.

1 complete set of forge tools with each forge.

1 surfacing plate.

6 swedge blocks, 200 pounds each.

1 welding block, about 6 inches square and 4 feet long, with three grooved sides, the grooves 2-inch, 3-inch and 4-inch die.

12 hand hammers.

6 flogging hammers.

6 sledges: two 6 pounds, two 8 pounds, two 12 pounds.

BOILERMAKER'S.

50 boilermaker's kits, to include hammers, chisels, caulking-tools, drift-pins, reamers, scrapers, etc.

12 sets riveting-hammers: 8 sets straight-pene, 4 sets ball-pene.

12 sets roller expanders, from 1¼-inch to 3-inch, varying ¼ inch.

1 power punch and shears, single machines, 15-inch throat, to punch 1 inch in ⅞-inch plate and shear 15 inches by ⅞ inch.

1 set hand-rolls, to be set on upper deck, rolls to be 6 inches diameter by 6 feet long.

6 rivet-heating forges.

1 dozen boilermaker's ratchets, short, with square shank-drills.

60 each of the following sizes of square shank-drills: ½-inch, ⅝-inch, ¾-inch and ⅞ inch.

6 tube cutters, to cut from 1½-inch to 3-inch tubes.

1 dozen flogging hammers, 4 pounds.

1 dozen sledges, 8 pounds.

6 clubs and sledges, for holding on.

6 screw punches.

1 steam engine, vertical, double cylinder, of 50 horse-power.

4 6,000-gallon evaporators No. 5, Type B.

4 No. 6 distilling apparatus sufficient for above.

Feed pump, capacity 30 gallons per minute.

Circulating pump, capacity 600 gallons per minute.
1 blower No. 4, 32 by 25 by 33h.
3 exhausts No. 5, 38 by 30 by 37h.

There will be about 140 mechanics and helpers, including machinists, boilermakers, blacksmiths, coppersmiths, patternmakers and moulders, so that it is readily seen that the repair ship will be almost invaluable to the fleet. A large force can be sent on board any ship needing extensive repairs to help the mechanics of the vessel, while on the *Vulcan* repair work of very large size can be done.

The work of running the machinery will be performed almost entirely by the mechanics and helpers, as care is taken in their selection to get a sufficient number of experienced men, and the others will be taught during service.

Distilling ship.—For modern war vessels with high-pressure boilers, fresh feed-water is a necessity, and there must be ample provision for a reserve supply. For ordinary steaming, the evaporators on board can usually furnish the extra feed needed, but it is not produced under the most economical conditions, as there is not space and weight enough for multiple-effect evaporators. For extended steaming at high powers, the reserve supply must be carried in the double bottoms, and when a fleet is likely to be away from a base where fresh water can be supplied cheaply in great quantity, special distilling ships become a necessity.

A distilling ship is practically a collier with an economical distilling plant of great capacity, and provided with sufficient tank capacity to be able to supply the immediate needs of a fleet.

The Navy Department, on the recommendation of Engineer-in-Chief Melville, is now pushing to rapid completion a distilling ship called the *Iris* (formerly the *Menemsha* of the Hogan Line). She will have a storage capacity for fresh water (in tanks and double bottoms) of about 1,000 tons, and will also carry about 2,500 tons of coal.

The distilling plant was designed, under the direction of Commodore Melville, by Passed Assistant Engineer Emil Theiss, U. S. Navy, of the Bureau of Steam Engineering.

It is to have a capacity of 60,000 gallons per diem as a multiple

effect apparatus when all the evaporators are in use, and the same capacity with the evaporators used singly, in case about one-third should have to be laid off for repair. When working triple effect, it is expected to get about 20 pounds of water for each pound of coal burned in the boilers.

The plant consists of four triple-effect units, each of which includes three evaporators and a condenser, with the necessary pumps. Provision is made to secure economy in every way, including feed-heaters using the exhaust steam from the pumps. Every detail has been carefully considered, and the design reflects great credit on Mr. Theiss.

The plant is being built by M. T. Davidson, the well known builder of pumping and evaporating machinery, who was the lowest bidder in the competition. He will deliver it ready for erection at the Norfolk Navy Yard, where the installation will be completed by Chief Engineer J. A. B. Smith, U. S. Navy, the efficient head of the Department of steam Engineering at that Yard. Mr. W. A. Drewett, the Superintendent at Davidson's (and an associate of the Society), has taken the greatest interest in the success of this plant, which is the first of its kind in the world, and is determined, if possible, to make it exceed the designed output, and to be as nearly perfect with respect to overhauling, cleaning, etc., as possible. We hope, in our next issue, to present a detailed account of the plant with illustrations.

MERCHANT STEAMERS.

Horatio Hall.—A passenger and freight steamer called *Horatio Hall*, was launched from the yard of the Delaware River Iron Shipbuilding and Engine Works, Chester, Pa., on March 23d. She is intended for the Maine Steamship Co.'s line between New York and Portland, Maine, and is 319 feet 4 inches long; 46 feet beam; 17 feet 6 inches deep. Her gross tonnage is about 3,300 tons, and she will be the largest vessel on any of the regular lines which run to the New England States. She has a cargo capacity of about 2,000 tons of freight, and is fitted with steam elevators to each hatch. The accommodation for passengers is very complete. There will be 130 staterooms. One of the special features is the provision made for an outside window for every stateroom on the ship. The dining saloon is on the spar deck, forward, and will seat 120 passengers. The total cost is approximately $350,000. The machinery consists of a triple-expansion engine, cylinders 28 inches, 48 inches, 75 inches by 4 feet 6 inches stroke of piston, and six Scotch boilers, the dimensions of each being 13 feet diameter, 12 feet long. Number of tubes in each boiler, 232; 3 inches diameter, and 8 feet 4 inches long. Number of furnaces in each boiler, 3; style of furnaces in each boiler, Morison, $\frac{9}{16}$ inch thick; inside diameter of furnaces, 40 inches; length of grate bars, 6½ feet; each furnace has a separate back connection. Grate surface in one boiler, 65 square feet; total surface in six boilers, 390 square feet. One donkey boiler, 100 pounds steam pressure; diameter of boiler, 9 by 10 feet long; 156 2½-inch tubes, 7 feet long; two furnaces, 3 feet diameter; grate bars, 6 feet long; grate surface, 36 square feet. She will have a speed of 17 knots an hour.—"American Shipbuilder."

A Modern Bulk Oil Carrier.—A contract was closed a few days ago with the management of the Roach ship yard, Chester,

Pa., for a vessel intended for the lighterage and transportation department of the Standard Oil Co., of which Mr. R. C. Viet, of New York, is superintendent. This vessel is expected to carry 720,000 gallons of oil in bulk. She was designed for both the coast and lake trades, and her length has therefore been limited to the size of the enlarged locks in the St. Lawrence canals, which it is said will be completed before the opening of navigation next year.

Dimensions of the vessel are: Length over all, 264 feet; length between perpendiculars (after side of stem to fore side of rudder post), 254 feet; beam, moulded, 40 feet; depth, 23 feet 6 inches. Machinery will be located in the center of this steamer, as it is claimed that central location of machinery in a vessel of this kind secures better trim, both light and loaded, and especially when considerable bunker capacity must be provided. Safety with the oil is amply provided for by cofferdams at both sides of the machinery space and by having separate pumps and pipes for the oil forward and aft of this space. Accommodations for officers and crew are also amidships in a bridge enclosure, which forms additional protection for the machinery and also enables the crew to attend to their work without the disadvantage of traversing the deck in bad weather. The oil tanks are so arranged that when eight central tanks are filled the vessel will draw about 16 feet. If the tanks at both ends are also filled the draught will be about 18 feet. This is done to fit the vessel for trade at ports where the draught is not suited to her full capacity. Bunker capacity for about 550 tons of coal is provided, so that the steamer may reach the most distant port in the trade in which she will be engaged, towing a barge, at 8 knots speed, and returning without replenishing fuel supplies if necessary to do so. The outfit includes all modern requirements, such as steam steering gear, steam windlass, steam towing machine, complete electric-light plant, etc. In structural features, as well as material, the hull of this vessel will be the same as other Standard Oil vessels —steamer *Maverick* and barges *57*, *58* and *81*.

Engines will be triple expansion, with cylinders of 21, 34 and 56 inches diameter and 42 inches stroke. A surface condenser

and independent air, circulating and feed pumps will be other features of the machinery. Two Scotch boilers of 14 feet 6 inches diameter and 12 feet 9 inches length, with three corrugated furnaces, will furnish steam at 175 pounds pressure.—"Marine Review."

Robert W. Wilmot and **Wm. H. Brown.**—Few vessels built on the lakes have attracted more attention than the ocean-going steel tugs *Robert W. Wilmot* and *Wm. H. Brown*, the former owned by W. G. Wilmot, of New Orleans, and the latter by W. H. Brown, of Pittsburg. Both were built by F. W. Wheeler & Co., of West Bay City, Mich., and both are intended for service on the Gulf of Mexico. They are the largest and most powerful tugs in the United States, and are fitted with everything in the way of modern appliances used on ships. The *Wm. H. Brown* was built very rapidly. Her keel was laid September 2, 1896; fifty days later (October 21) she was launched, and she left the shipyard November 11 under her own steam.

The principal dimensions of these tugs are: Length over all, 156 feet 8 inches; length between perpendiculars, 143 feet 4 inches; moulded beam, 28 feet; moulded depth, 17 feet. On account of the very powerful machinery with which they are fitted, and the requirement that they should be able to cross the Atlantic safely, the tugs were made very strong, their scantlings exceeding the highest requirements of the standard registers. Accommodations for owners and crew are provided in a steel deck house 16 feet wide, extending well forward and aft. In this deck house are located the dining room, galley, wrecking room, engineers', oilers' and deckhands' rooms, commodious room for owners, and towing machine room. The pilot house and texas, in which are the captain's and mates' rooms, are above this deck house and are also built of steel. The interior of the pilot house, dining room, engine room, and owners' and officers' rooms are panellel with mahogany. Large sidelights are fitted wherever necessary. A distilling plant of 2,000 gallons capacity per day is located in the engine room, and a fresh-water receiving tank, holding 1,000 gallons, is placed in the hold forward. Aft of the engine room is a dunnage room about 11 feet in length and extending across

the entire width of the ship. One of the American Ship Windlass Co.'s steam windlasses is placed forward and a steam capstan aft. In the after end of the deck house is a steam-towing machine, having 14 by 14-inch cylinders, also of American Ship Windlass make, and a wire cable of 1¾ inches diameter and 200 fathoms length. The steam steering engine is of Williamson Bros.' (Philadelphia) make. There is also a complete electric plant on board, with incandescent lights for all parts of the vessel and a search-light on top of pilot house. The rigging in both tugs is from two steel spars. There is a full set of sails to be used in case of emergency.

The type of engine fitted in both tugs is inverted, direct-acting, surface-condensing, triple-expansion, with cylinders 20, 32½ and 55 inches, and a common stroke of 36 inches. The cylinders are placed in the order high-pressure, intermediate-pressure and low-pressure. The low-pressure cylinder has a double-ported slide valve, and the intermediate-pressure and high-pressure have single-ported piston valves with spring rings. All valves are worked by the Stephenson double-bar link motion, with adjustable cut-off arrangement, and the valve motion is controlled by a steam reversing gear.

The bedplate is of the box-girder type, cast in one piece with five large main journals. The front columns are of the straight box type, provided with the necessary brackets and journals to support the reverse shaft, and the back columns are cast on the condenser with large bearing surface for the crosshead slippers. The condenser is cast in three sections, having ground joints strongly bolted together, and it contains a cooling surface of 3,000 square feet.

The crankshaft is of wrought iron with steel pins and of the built-up type, 11 inches diameter, with cranks set at angles 120 degrees apart. The thrust-shaft has eight solid thrust-collars, forged on, and the thrust-bearing is of the ordinary horseshoe type, with eight driving collars, faced with anti-friction metal. The propeller-shaft is 11½ inches in diameter in the stern-bearing, which consists of a cast-iron sleeve in halves, and four sections, 4 feet 6 inches long, arranged so that the sleeve can be

removed without unshipping rudder or propeller. The propeller is of the sectional type, cast steel, four blades, and secured to shaft by taper and nut.

Connecting rods are of wrought iron with upper ends forked to suit crosshead, and the usual bolt connections. The crossheads are of wrought iron with double gudgeons and slipper forged on. Piston rods are of the best machinery steel with tapered ends and nuts for securing pistons and crossheads. The pistons are of cast iron in H.P. and I.P. cylinders, and of cast steel of conical shape in L.P. cylinder. The engine is fitted complete with balance pistons for I.P. and L.P. cylinder valves, balanced throttle valve, worm-pinch gear, cooler service, relief valves for cylinders and valve chests, and all necessary instruments, such as steam and vacuum gauges, clock and revolution counter, and the cylinders are neatly lagged with sheet steel. Both air and circulating pumps are of the independent duplex type, having bronze rods and lined with brass. Condenser and air pumps are so designed that the engine can be worked jet condensing at any time.

Steam is furnished at 180 pounds working pressure by two return-tubular cylindrical boilers, 12½ by 12½ feet, having three 40-inch Adamson furnaces. A 50-inch fan is provided for forced ventilation in fire-hold. When engines are running at 800 feet piston speed per minute, under 180 pounds steam pressure, these vessels are expected to develop a speed of 20 miles an hour.—"Marine Review."

Cape Charles.—When the railroad connecting Cape Charles City, Va., with the northern cities was completed some years ago, and a through route between Norfolk and New York was established *via* the eastern shore of Virginia and Maryland, several steamers were built to ply between Cape Charles City and Norfolk, a distance of 36 miles. At present the *New York* and the *Old Point Comfort*, a propeller and a side-wheeler, respectively, perform the service. The demands of travel necessitate the addition of another boat, and a contract has just been made between the New York, Philadelphia & Norfolk R. R. Company and the Delaware River Iron Shipbuilding and Engine Works (Roach's

Shipyard) for a new passenger propeller which will, when placed in commission on the route, be the largest and best of the fleet engaged in the service. The line formerly owned a steamboat called the *Cape Charles*, but she was sold and has since burned in southern waters, and so it has been decided to name the new boat the *Cape Charles*.

The hull will be of steel, with numerous bulkheads. It will be 230 feet long, and the draught of water will not exceed 9½ feet with 250 passengers and 250 tons of baggage and express matter on board. In order to get into the harbor at Cape Charles on all stages of the water it is necessary that the vessel shall draw less than 10 feet. Over the guards the beam will be 41 feet, and the depth of the hold will be 15 feet.

There will be a triple-expansion engine having cylinders 19, 32 and 50 inches in diameter, with a piston stroke of 28 inches. It will develop 1,400 horse power. Steam will be supplied by two boilers working at a pressure of 170 pounds to the square inch. These boilers will each be 13 feet in diameter.

The contract calls for a speed of 18 miles an hour.

The *Cape Charles* will be completed sometime during the summer and will be placed upon the route immediately.—"Seaboard."

The Largest Steamer on the Great Lakes.—This title is properly attributable to the mammoth steamer which is being constructed at the shipyard of F. W. Wheeler & Co., West Bay City, Mich., for the Bessemer Steamship Company, of Cleveland, O. The longest lake steamer now afloat is the *Sir William Fairbairn*, which measures 434 feet over all. The new boat will be 42 feet longer, or 476 feet in length over all. On the keel the boat will be 456 feet in length, and the breadth of beam will be 50 feet, while the depth of hold will be 29 feet. The capacity of this boat, on a draught of 17 feet of water, is estimated at 6,100 tons of iron ore.

The machinery will consist of a quadruple expansion engine, with cylinders, 26½, 37, 54½ and 80 inches in diameter by 42 inches stroke. Steam will be supplied by four steel boilers, allowed 200 pounds pressure. These will each be 13 feet 4

inches in diameter by 11 feet 6 inches in length, and are being constructed by Wickes Bros., East Saginaw, Mich.

Maida.—The new steel barge *Maida* recently launched at the shipyard of the American Steel Barge Co., West Superior, is a vessel capable of carrying about 6,400 net tons on 16½ feet draught. A description of this vessel will prove interesting, as she may be classed among the best of modern lake barges. The *Maida* will be owned by the Minnesota Steamship Co. She was practically ready for service when launched. Her dimensions are: Length over all, 390 feet; length between perpendiculars, 376 feet; beam, 46 feet; moulded depth, 26 feet; registered tonnage, 3,474.78 tons gross and 3,210.74 net. The vessel has main deck beams but no deck laid on them, as she is intended for bulk freight, mainly iron ore. The spar deck forward is raised to the height of the main rail, so as to form a forecastle for crew's quarters, steam towing machine, etc. In the deck house aft, which is also of steel, are located pilot house, officers' quarters, dining room, etc. There is a water bottom of 4½ feet depth and 2,500 tons water ballast capacity.

The cargo hold contains three collision bulkheads, one forward and two aft. Space between the after bulkheads is used as a wrecking well. The channel system prevails in construction of the vessel. There are thirteen cargo hatches of 24 feet centers, each hatch being 28 by 8 feet in the clear. One of the hatches is a trunk hatch, running down from the forecastle, which permits of cargo being loaded well out to the extreme forward part of the vessel.

The *Maida* will be rigged as a three-masted schooner, similar to the barges *Constitution* and *Nasmyth*. Masts will be of steel, 92 feet in length, and the spread of canvas will be sufficient to enable her to make port in event of accident to the towing steamer. The outfit will include an electric-light plant, steam towing machine for handling of tow lines, and three steam winches for handling of mooring lines; also steam steering gear, steam windlass and capstans, ballast pumps, etc., all of which will be supplied with steam from a Scotch boiler at 120 pounds pressure.

America Maru.—On Wednesday afternoon, March 9, there was launched from the Shipbuilding Yard of C. S. Swan & Hunter, Limited, Wallsend-on-Tyne, a twin-screw passenger and mail steamer, which has been built to the order of the Toyo Kisen Kabushiki Kaisha of Tokio, Japan, better known as the Oriental Steamship Co. of Tokio, for carrying passengers and mails between China, Japan and San Francisco, thus making the connection with the Union Pacific and the Southern Pacific Railways.

The steamer is 441 feet in length by 51 feet beam and 32 feet 6 inches deep to the upper deck. She has a clipper cutwater with bowsprit, and has a top gallant forecastle, a long bridge-house with promenade deck above it, and a long poop. She is fitted up in luxurious style for the accommodation of 89 first-class passengers at the fore end of the bridge and under the promenade deck; accommodation is also provided for 28 second-class passengers in the poop, and for 200 steerage passengers in the 'tween decks forward. Comfortable quarters are also provided for the crew aft on the main deck, whilst the officers are accommodated at the after end of the bridge. The steamer has been designed to carry a large measurement cargo on a deadweight capacity of about 5,000 tons, to cope with which cargo she is supplied with a large number of powerful winches and other discharging gear. Water ballast will be carried in the peak tanks and in the cellular double bottom.

The machinery will be supplied by the Wallsend Slipway and Engineering Co., Limited, and consists of two sets of exceptionally powerful engines, each having cylinders 28¼ inches by 46 inches, and 75 inches diameter by 48 inches stroke, supplied with steam by five boilers having a total heating surface of about 20,000 square feet, and capable of developing about 7,500 I.H.P. and of propelling the steamer at a speed of 16½ knots per hour. The propeller blades are of manganese bronze, and special attention has been paid in the engine room, and in the outfit and general details of the steamer to successfully carry out the important work which she will undertake. The requirements of Lloyd's classification, the Board of Trade, and the Japanese Government have all been strictly adhered to, and special attention will be paid

in fitting up the accommodation to the comfort of the passengers in hot climates. A complete installation of refrigerating machinery with cold-storage rooms will be provided, and the steamer lighted throughout by electricity.

Bræmar Castle.—Messrs. Barclay, Curle & Co., Limited, Whiteinch, launched on the 23d of February, the *Bræmar Castle*, a screw steamer of about 6,200 tons gross, built for the intermediate service of the Castle Mail Packets company. The hull is built of steel throughout to the requirements of the Board of Trade for a foreign-going passenger steamer, and the subdivision by bulkhead and cellular double bottom has been specially attended to. The dimensions of the vessel are as follows: Length over all, about 470 feet; length on water line, 450 feet; breadth, extreme, 52¼ feet; depth, moulded, 33½ feet; depth, hold, 30½ feet. The height from the keel to the top of the promenade deck is about 52 feet, and to the navigating bridge about 60 feet. The vessel will have accommodation for over 70 first-class passengers forward of the machinery space on the upper and bridge decks; 130 second-class, amidships on the main and upper decks, and 160 third-class aft, in the 'tween decks and the poop, while the remainder of the 'tween decks has been fitted so as to be available either for additional third-class passengers or for transport service. Some of the state rooms are for single passengers, most for two, while others are arranged as family cabins for four, with doors communicating from one room to the other. Electric light, refrigeratering appliances and all the other accessories of the first-class liner are included in the equipment. The boats will be sixteen in number, placed on top of the promenade and poop decks. The propelling machinery is of the quadruple-expansion type, balanced on the Yarrow-Schlick-Tweedy system, which arrangement has been adopted by the Castle Mail Packets Company on account of the advantages it offers, not only as regards economy, but also in practically abolishing the vibration of the ship due to the machinery.

Haliotis.—Messrs. Sir W. G. Armstrong, Whitworth & Co., Limited, launched the steamship *Haliotis* from their Walker Yard on February 22. The dimensions of the boat are: 248

feet 6 inches over all, 40 feet moulded, and 17 feet 3 inches depth moulded. The vessel has been specially constructed for the carriage of petroleum in bulk, under the supervision of Messrs. Flannery, Baggallay and Johnson, of London and Liverpool. There are one or two unusual points about this vessel, she being intended to use liquid fuel on her service in the East, and her engines and boilers have been fitted out with this special view. She is constructed on the trunk turret system, which gives a larger carrying capacity in proportion to register tonnage than the ordinary form of construction. The engines are, for special reasons, of the compound surface-condensing type, taking steam from two boilers at 100 pounds working pressure, and the cylinders are 30 inches and 63 inches in diameter by 39 inches stroke. Electric light is fitted throughout the vessel, and there is a complete installation of duplex pumps for prompt dealing with oil cargo. The bunkers of the vessel are stayed, riveted and caulked so as to contain oil fuel, and they are also so arranged as to be available for coal in case of emergency.

Superior City, is being built for the Zenith Transit Co., of Duluth, A. B. Wolvin, president and general manager. She is 430 feet between perpendiculars, 450 feet over all, 50 foot beam, and 28 feet deep. She is built of open-hearth steel throughout, on what is known as the transverse system of channel-bar construction; that is, with channel-bar floors, channel-bar frames and deck beams. The big boat has a 5½-foot water bottom, extending from collision bulkhead to engine room bulkhead, divided into twelve water-tight compartments. The lower hold is divided into six compartments by five screen bulkheads, thus enabling this ship to carry six different kinds of grain or coal at one and the same time, making the most complete general cargo freight boat that has ever been built.

Her main deck beams will be laid every eight feet apart, but no deck. The spar deck will be entirely of steel, with thirteen hatches located in the same, 24-foot centers each. This is so as to enable the ship to be loaded or unloaded by working all the hatches at the same time, the grain, ore and coal spouts and ore hoists all over the lakes being uniform centers of 24 feet. The

steamer will have three steel pole spars, steel cabins located forward and aft, for the accommodation of the crew. She will have steam windlass and capstan forward, steam capstan aft, with the Cleveland Shipbuilding Co.'s special arrangement for hand and steam gear located in the pilot house. There will also be located on the spar deck three of the Cleveland Co.'s patent winding engines for the handling of wire mooring lines. This is something new in lake practice, it having been used on the ocean for some time in the manipulation of large vessels.

The ship will be lighted throughout with incandescent lamps. There will be two direct-connected dynamos and about 275 incandescent lamps throughout the ship, which includes all of the signal lights on the spars, etc. She will also have six arc lights for lighting the deck, so that the ship can be loaded or unloaded night or day. One of the special features in this ship is the raising of the deck from the boiler house aft, making what is known as a poop deck, the houses aft being located all below this deck.

The motive power of the *Superior City* will consist of one quadruple expansion engine, having high-pressure cylinder, 17 inches in diameter; first-intermediate cylinder, 25½ inches in diameter; second-intermediate cylinder, 39 inches in diameter; low-pressure cylinder, 60 inches in diameter, with common stroke of 40 inches. She will have a compound air pump and condenser, two ballast pumps, feed pump, pony pump, bilge and cold-water pumps. The boiler power will consist of Babcock & Wilcox water-tube boilers, of a combined heating surface of 7,000 square feet, to be allowed a working pressure of 250 pounds of steam to the square inch. It is expected that this vessel will carry about 7,000 gross tons of ore on the present draught of water and about 3,000 tons of water ballast. She is built very strongly, with the expectation of loading to the anticipated depth of 20 feet when the lake channels shall have been deepened to this extent. She is expected to be ready for sea about the first day of May, and when completed will cost about $225,000.—"Seaboard."

Kaiser Wilhelm der Grosse.—The North German Lloyd steamer *Kaiser Wilhelm der Grosse* has again lowered the record from Southampton to New York. She arrived in New York on

the 6th April, having made the passage in 5 days and 20 hours, which is 2 hours and 35 minutes less time than her best previous record from Southampton, which was made on her maiden trip, in September of last year. On that trip she covered a distance of 3,050 knots, at an average speed of 21.39 knots. On this last trip she covered 3,120 knots, increasing her average speed to 22.29 knots.

Pennsylvania R. R. Ferry Boat.—At Roach's shipyard, the Delaware River Iron Shipbuilding & Engine Works, Chester, Pa., there are now six vessels, representing a value of over a million and a quarter of dollars, under way, and a seventh, a New York ferry steamer for the Grand street line, is in the water ready to leave. The latest contract secured by this company is from the Pennsylvania Co., for a ferry steamer to go on the route between the Jersey City terminal station of the Pennsylvania Co. and the Twenty-third street station in New York. This steamer will be constructed of steel and the hull will be 206 feet long, having a moulded beam of 46 feet, and a beam over all of 65 feet, with a depth of hold of 17 feet. The upper works will be very substantially built of the best joiner work, and the two great cabins will afford room for carrying a large number of passengers. The general arrangement and appearance of the cabins will be similar to the other three vessels in the same service, but the boat will contain many improvements over their designs, the result of the experience of Mr. H. S. Hayward, who designed the vessel. The cabins will be finished in ivory painting with panels of staff in embossed designs and mahogany railings and columns. The floors on both decks will be covered with interlocking rubber tiles. There will be two propellers on each end of the steamer, the wheels being 7 feet 10 inches in diameter and cast from open-hearth steel. The power will be furnished by two compound engines of the three-cylinder type each with a high-pressure cylinder of 20 inches in diameter and two low-pressure cylinders 32 inches in diameter, with a stroke of 24 inches. Steam will be generated by four Thornycroft water-tube boilers, each with 60 square feet of grate surface and 2,295 feet of heating surface given by 420 tubes. There will be two smoke stacks. The boat will

make about 17 miles an hour, a high speed being necessary on account of the long run up the North river and the necessity of prompt connections.

Arizona.—The old Fairfield-built *Arizona* is about to start on a new lease of life on the Pacific, where it is hoped she will be the initiator of as rapid a development in steam navigation as followed her advent on the Eastern ocean. Nineteen years have passed since the *Arizona* was completed by Fairfield, and in the interval we have seen a wonderful development. The *Alaska* followed the *Arizona*, and the success of the newer and faster boat practically commenced the Atlantic race. To the eastward "the old *Arizona*" held the record with 7 days 12 hours 24 minutes, and to the westward with 7 days 10 hours 49 minutes. However, in the keen competition even this performance has long since been excelled; indeed, for nearly six years the *Arizona* has lain idle, but notwithstanding this spell of leisure the hull, which is of iron, is nearly as good as ever it was.

When it was decided to transfer her to the Northern Pacific Steamship Company, she was placed in the hands of her builders for renovation. The accommodations for passengers of all classes, in what might be described as the North Atlantic style, is swept away, and instead there is amidships, and perfectly isolated, accommodation for forty first-class passengers. The state rooms are bigger and airier than one finds in any vessel of the type, and, in addition to a handsomely fitted and furnished dining saloon, there is a comfortable smoking room for gentlemen and a charmingly furnished apartment for ladies. As she goes east now the vessel is capable of carrying 6,100 tons of tea at its measurement tonnage and 1,000 emigrants, and a lead-lined space has also been set apart for the carriage of silk, for which the freight is considerable. The speed of the ship on her original trial was 17.3 knots. Her engines have now been tripled, and new boilers fitted. On four runs on the measured mile at Skelmorlie she averaged almost 15½ knots, and on two runs between the lights nearly 15¾ knots.

YACHTS.

Sovereign.*—The yacht was designed by Mr. J. Beavor-Webb, of New York, and the hull built by the John N. Robins Company, of South Brooklyn. The design of the main engines Mr. Webb entrusted to Mr. John H. Macalpine, of Washington, D. C., and they were built by the W. and A. Fletcher Company, of Hoboken, N. J.

The engines are triple-expansion, with cylinders of 15 inches, 24 inches and 39 inches in diameter and 21 inches stroke. The steam pressure is 225 pounds per square inch. The principal peculiarity of the design lies in the framing, which is similar to that introduced by Mr. Macalpine in the engines of the *Ketcham*, trading on the Great Lakes.

The objects of the design were to make a light, simple and very open framing in which little hand fitting or forging would be required, and at the same time secure rigidity by avoiding all cross-bending on the various members.

The nature of the framing is shown clearly by the engravings. The rods in the present case were of steel, supplied by the Bethlehem Steel Works, and the castings at the junctions of the diagonals and columns, into which the rods are screwed, are of cast steel. The condition which must be fulfilled in order that the framing should go together off the machines, is that the castings should be bored and tapped accurately to the correct angles. To insure this it was only requisite to make a plate to which the castings could be bolted, and to which bearings were attached for guiding the boring bars. To bore out the hole for the horizontal bar a bridge was bolted to the plate by fitted bolts. This bridge took the upper end of the boring bar, while the lower end was guided by a hole in the plate itself. In dealing with the

* The *Sovereign* has been purchased by the Navy Department and renamed the *Scorpion*.

castings at the upper ends of the front columns, which also take diagonals, the upper face, which bolts to the cylinders, was first planed off. Then this face was butted against a recess in the plate of the special tool, so cut that the casting would then stand in proper relation to the boring bars. Thus for all operations performed by this tool each casting required to be set only once.

The diagonals between the front and back columns had right and left-hand screws cut on the ends, so that in putting together the framing it was only necessary to turn these diagonals till the attached columns stood at the proper distance shown by a gauge.

The horizontal bar of the engine, to which the lower ends of the main guides are attached, is a round bar turned from end to end. A cut is planed off, about $\frac{1}{8}$ inch deep, to form a flat surface, which would give good support to the fitted bolts by which the guides are attached, and for the substantial set screws tapped into the front of the junction castings to hold against the pull on the horizontal bar when the engine is going astern. All nuts of the framing were secured by being firmly screwed up on thin copper washers.

To insure the absence of cross-bending stresses on the rods of the framing, the forces acting at any junction must pass through the point of intersection of the various numbers. The whole engine then becomes practically a rigid body, and there will be no sensible yield till the point of total breakdown was reached. This involves splitting the back columns and diagonals at the junction; but, as there could be no side yield at this point, no weakness was introduced.

Longitudinal stability is obtained by bolting the horizontal bar firmly to the air pump, as shown, the air pump being in turn firmly bolted to the bed plate. The main guides are attached to the horizontal bar by carefully-fitted bolts, and, at the top, strongly secured to the cylinders, thus completing the longitudinal stability of the engine.

It is important in all light framings to avoid redundancy as much as possible, and this is done in the present case by fitting only two diagonals between the front and back columns. There is thus only left the redundancy which indispensably accompa-

Fig. 1.

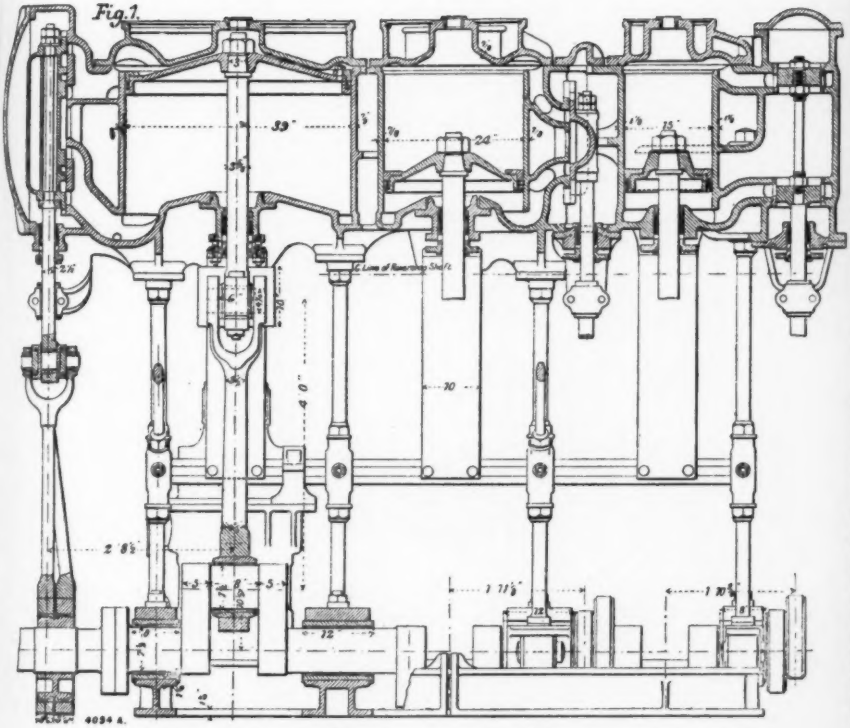


Fig. 2.

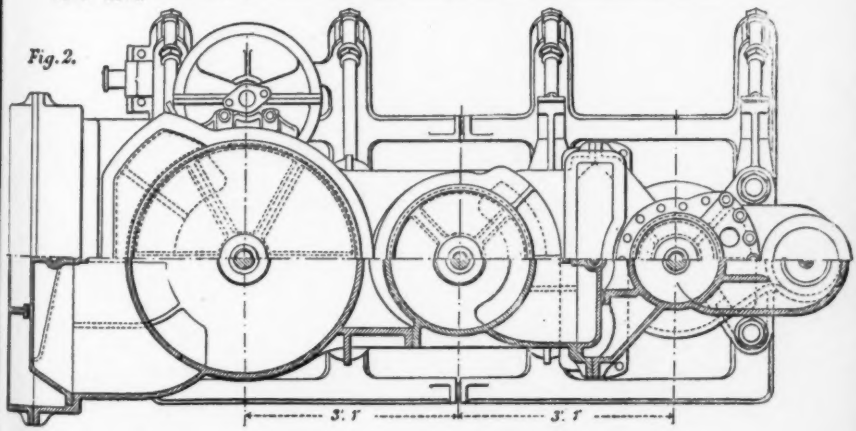


Fig. 3.

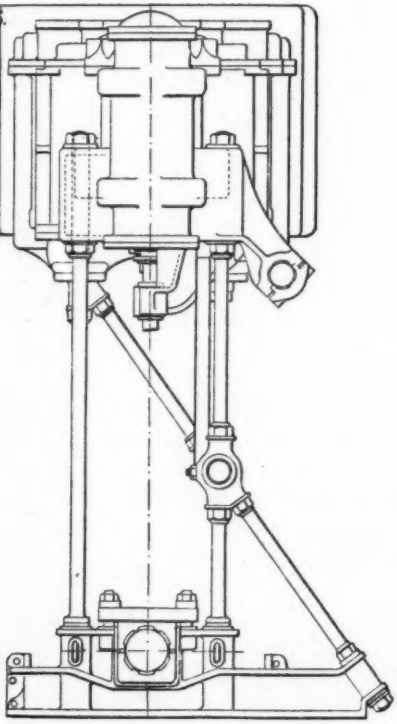


Fig 4.

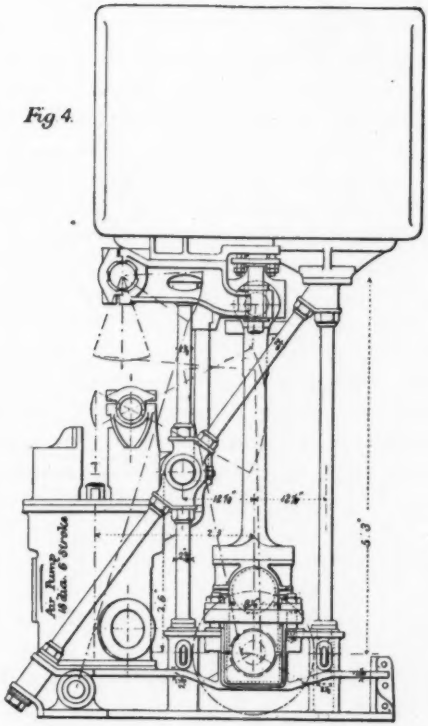
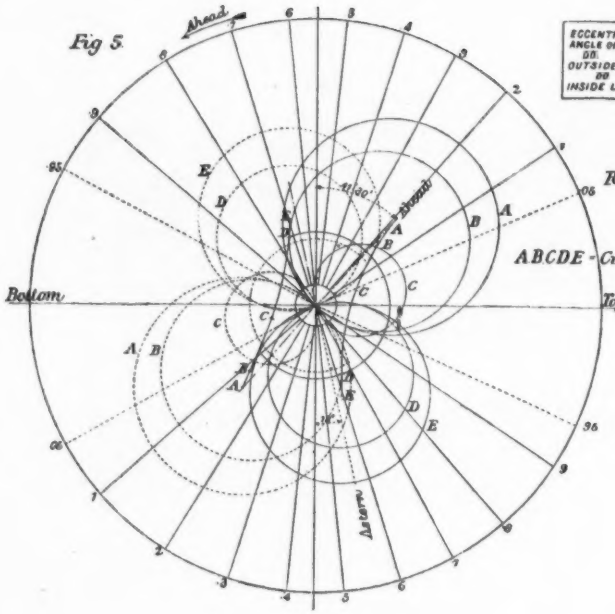
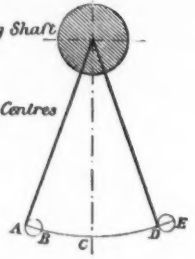


Fig 5.



ECCENTRICITY OF ECCENTRICS = 2".
ANGLE OF ADVANCE – AHEAD ECCENTRIC = 45° 30'
DO. DO. – ASTERN DO. = 13° 0'
OUTSIDE LAP – TOP = 1/16.
DO. – BOTTOM = 5/8.
INSIDE LAPS – NEGATIVE = 1/4.

Fig. 6.



nies the bolting of all three cylinders together, and each member is submitted to a stress which is nearly definite and which is easily calculated for each set of circumstances.

The valve gear is of the Stephenson type, reversed by a steam cylinder with hydraulic controlling cylinder pivoted to the bedplate and catching the reversing shaft just beside the low-pressure reversing lever, so that the heavy stresses of this gear can produce no sensible torsion of the shaft. The gear and reversing engine are merely shown by center lines on the end elevation.

We also give the Zeuner diagram of the valve motion. The rods are crossed, and the angles of advance of the ahead and astern eccentrics are seen to be very different. The effect is to give a diminishing lead as the gear is linked up from full ahead position, the pre-admission remaining nearly constant. This setting makes the gear available over a long range of cut-off; and a sufficient astern motion is got without throwing over the links so far as straight gear. A very large lead can be used at the long cut-offs, and hence the necessary admission area is got with a comparatively short stroke of valve. As the gear is linked up, no doubt the maximum steam openings diminish rapidly. But this maximum opening then occurs at an earlier part of the stroke and consequently for a smaller speed of piston, even if the revolutions remained constant. In a marine engine the revolutions vary approximately as the square root of the cut-off, the loading of the ship remaining the same. Taking all these factors into account, it will be found that the inlet speed at maximum valve opening does not increase unduly as the gear is linked up.

A small range of independent adjustment is given to each gear by making the pins which held the drag rods eccentric to the part passing through the reversing lever, as indicated by the small circles at the outer end of the reversing lever diagram. The intention was to find by trial the best position for these pins, and key them up permanently, so that the valve setting could not be readily tampered with.

Letters are marked at several points of the reversing lever diagram, Fig. 6, and the consequent valve motion is shown by cor-

responding letters on the curve of centers and circles of the Zeuner diagram, Fig. 5.

The engravings are from the original sketch from which the details were copied, but the finished engine involves no sensible deviation except that the cast-steel bedplate was deepened a few inches, as it was not desired to dish the ship-plates in the crank-pits.

The building of the engines was excellently carried out by Messrs. Fletcher, and, since their completion last season, the engines have given great satisfaction.—"Engineering."

Felicia.—The John N. Robins Company recently launched the steel steam yacht *Felicia*. The new vessel is building for Col. E. W. Bliss, and will belong to the New York Yacht Club. The hull is of steel, 179 feet over all, 142 feet 4 inches on water line, 20 feet beam, extreme; 11 feet deep and 6 feet 3 inches draught. The forward deckhouse is 26 feet long, and will be used as a dining room. The captain's stateroom is in the after portion of this house, on the starboard side, and on the port side is the dumb-waiter, running to the galley below. The after deckhouse, to be used as a ladies' room, is 18 feet long, from which the saloon companionway will lead. These houses and all deck fittings are to be of polished mahogany. The forecastle is roomy, and will be fitted in a convenient and comfortable way. The mess room is spacious, and two state rooms aft the latter, which are intended for the chief engineer and steward, will be found to be pleasant quarters. Then, still going aft, comes the galley, and, in turn, the engine and fire rooms and boilers. A wide air space follows, and then there are four state rooms, two on either side, with bathrooms, after which is the saloon. There is another state room aft the saloon, on the port side, and opposite it a store room fitted for the requirements of the owner and his guests. A passageway leads to the owner's quarters in the after portion of the ship, and these are the full width of the vessel. Then comes a large room for general storage purposes. The saloon and state rooms will be finished in white and gold. The engines are of the triple-expansion type, with four cylinders, 14, 21, and two of 24 inches in diameter by 18 inches stroke of

piston. These were built by John W. Sullivan, of South street, New York. Steam will be supplied by two Roberts water-tube boilers having a pressure of 250 pounds to the square inch.

Chetolah.—This entire boat and machinery were designed and built at Newburyport for Capt. Charles Lunt, a retired shipmaster of that place. Hull by L. Marquand, of Salisbury, and machinery by C. R. Sargent, Newburyport, Mass. The hull is 110 feet over all, 89 feet water line, 16 feet 6 inches beam, and, when ready for sea with bunkers full of coal, draws 8 feet 6 inches. Frame of white oak, cut there; planking, Western oak 2½ inches thick; ceiling, Georgia pine; deck, white pine 2½ inches square; deck houses, companionways, etc., mahogany. The yacht is lighted by electricity, and Mr. Wise, the present owner, has just purchased for her a powerful searchlight and electric launch. There are five large staterooms and a bath and toilet room, besides the main saloon. The dining room is in the deck house and is 18 feet long by 12 feet wide. The entire woodwork is solid mahogany. The crew are quartered aft.

The motive power is a 500-horse power triple-expansion engine with cylinders 11½, 18 and 30 inches by 16 inches stroke, all the cylinders being fitted with piston valves worked by a radial valve gear, each valve having an independent cut-off and the whole reversed by steam. Cranks set at 120 degrees and are "built up." Pins are 5¾ inches diameter by 6 inches long. Shaft, forged steel 6 inches diameter. Wheel, 6 feet diameter, 9 feet six inches pitch, Tobey make. All pumps are independent.

Steam is furnished by a Hodge upright tubular boiler 8 feet 9 inches diameter, 9 feet high. It has a double furnace with water leg between and 750 tubes 2 inches in diameter and 6 feet long. Grate surface, 47½ square feet. Shell is ¾-inch Spang steel, butt and strap riveted. Working pressure, 165 pounds. Cruising (for which the boat was especially designed), engine makes about 155 revolutions and 12 knots by the log. They find this to be the most economical speed, all things considered. Under natural draft there is no trouble in running engines at 200 revolutions, which shows 13¾ knots by log. Since the death of Captain Lunt, about a year ago, the *Chetolah* has changed hands. She

is now the property of Mr. Albert J. Wise. The vessel is valued at $30,000.—"American Shipbuilder."

Llewellyn.—One of the handsomest and fastest pleasure craft in these waters is the steel steam yacht *Llewellyn*, owned by Alfred Carr, of New York. This yacht was formerly the *Marietta*, and was built by the Pusey & Jones Co., of Wilmington, Del., for Harrison B. Moore, of New York, from designs by Henry J. Gielow. In preparing the plans of this boat the principal ends in view were good accommodation and economical maintenance of a reasonably high speed for a cruising craft.

The yacht is 142 feet 6 inches over all, 118 feet load-water line, 16 feet beam, 8 feet 11 inches depth of hold, and 6 feet 6 inches mean draught. The hull is of mild steel, the keel being $5\frac{1}{2}$ inches by $1\frac{1}{8}$ inches; frames, 2 inches by 2 inches, 3 pounds per foot; floors, 10 inches deep and from $\frac{3}{16}$ to $\frac{1}{4}$ inch in thickness; plating, from $\frac{3}{16}$ inch to $\frac{5}{16}$ inch thick. The bulkheads are three in number, a collision bulkhead forward and one at each end of engine space. The deck is flush, broken only by a low trunk over the owner's stateroom. The deck house is 18 feet long, serving as a social hall and dining room, a dumb waiter leading to the galley below.

The crew is berthed in the bow, then comes the captain's room, galley and engine space. Abaft this there are four staterooms so arranged with a folding bulkhead between them that they may be thrown into one large room the full width of the yacht. The saloon is 15 feet long, furnished in the usual way for day use, but with folding berths and curtains by which it can be divided into four separate rooms. Abaft of the saloon is the companion, with toilet room to port, and a stateroom, 10 feet long and extending the full width of yacht, the low trunk giving ample light and head room and superior ventilation. The toilet room is fitted with bath tub, plumbed for hot and cold, fresh as well as salt water. The yacht is lighted by electricity.

The engine is triple-expansion, the diameter of cylinders being 12 inches, 18 inches and two 20 inches, with a uniform piston stroke of 15 inches. The bed plate is of cast steel. The cylinders are supported by eight $1\frac{1}{8}$-inch steel columns, well connected

and braced diagonally. All the moving parts are of steel, as light as due regard for strength as well as durability will permit. The bearings and pins are large, so as to run perfectly cool under all conditions.

The valve motion is taken from a parallel shaft, geared to main crank shaft, and the reversing is effected by means of a sleeve on a parallel shaft, one end with a straight slot working on a feather in one of the gear wheels, and the other end having a spiral slot working on a feather on parallel shaft. By moving this sleeve in and out the necessary angular advance is obtained for operating the valves. The latter are all piston valves, fitted with packing ring.

The condenser has a copper shell to save weight, and has 482 $\frac{5}{8}$-inch tubes 5 feet long. Air and circulating-pumps are of standard make. The propeller is four-bladed, 4 feet 9 inches in diameter, of cast iron. The engine is carefully balanced and is entirely free from any vibration, making 310 revolutions ordinarily, but can be driven in excess of 350 revolutions per minute. The machinery was built by John W. Sullivan. There are two Roberts water-tube boilers, 5 feet wide, 7 feet 9 inches long by 6 feet high, about 24 square feet of grate each, and about 800 square feet of heating surface each. The *Llewellyn* is valued at $50,000.—"American Shipbuilder."

BOOK REVIEWS.

RESISTANCE AND PROPULSION OF SHIPS, BY PROF. WM. F. DURAND, OF CORNELL UNIVERSITY. Published by John Wiley & Sons, 53 East Tenth street, New York City.

To the readers of the JOURNAL, who are familiar with his frequent contributions to its pages, it is hardly necessary to say that any work from the pen of Prof. Durand is sure to be excellent and worthy of careful study. The present work is the result of his lectures at Cornell for several years, during which he found that no treatise on the subject gave the treatment best adapted to instruction nor the latest data. He has embodied the latest information obtainable from the proceedings of professional societies abroad as well as important data from his own experiments. Prof. Durand is noted for the lucidity of his exposition of a subject, and, while he has not hesitated to use the higher mathematics, as is necessary in treating his subjects, he has so arranged the text that readers whose mathematical knowledge is limited, may still get almost the full value of the work.

Space forbids a detailed examination of the contents, but, as might be expected, the two subjects mentioned are very carefully and exhaustively discussed. The aim has been not merely to explain thoroughly but to give a condensed account of the views of the various authorities, as well as references to their works.

Some familiar topics are presented in new and attractive form with demonstrations by the author, a notable instance being the Law of Comparison or Kinematic Similitude. Indeed, the author has added valuable information of his own to nearly every feature discussed.

The final chapter on Trial Trips will prove of special interest

and value to ship and engine builders, and to all those, including naval officers, who have to conduct or observe trials. The various methods are thoroughly discussed and the merits and disadvantages pointed out. This will prove of great value, for it often happens that the limitations of certain methods are not well understood and they are carried beyond the point where accuracy can be insured.

The publishers have done their part with the excellence which characterizes all their work, and we can congratulate them and Prof. Durand on this excellent treatise, for which we predict great popularity.

MORISON SUSPENSION FURNACES. — The Continental Iron Works, of Brooklyn, have recently issued a very handsome catalogue, giving illustrations and complete data for the use of the Morison Suspension Furnace, of which, as is well known, they are the sole manufacturers in this country. The catalogue will prove very valuable to all designers who have occasion to use corrugated furnaces. In addition, a considerable portion is devoted to the subject of internal-combustion boilers with the Morison furnace, of which a number of cuts are given together with complete figured dimensions, so that a designer would have little more to do for the powers given than get the design and specification in the catalogue.

The Continental Iron Works will doubtless furnish a copy of this catalogue to all designers who make application for it.

LUBRICANTS, OILS AND GREASES; BY I. I. REDWOOD.—Published by Spon and Chamberlain, No. 12 Curtlandt Street, New York City.

This is a brief work which gives a considerable amount of information with respect to the subjects covered by the title, and doubtless all readers will receive some help from its perusal. In a work of such small size, only fifty pages, one cannot expect the subject to be treated exhaustively; and it would seem from the amount of space given up to greases, more than half the book,

that the author is evidently a believer that they are better than oils as lubricants.

The book explains the difference between the mineral or hydrocarbon oils, and the vegetable or animal oils, and points out the cases in which one kind or the other is best adapted to use. It also explains many of the terms which are commonly used by dealers in oils, which will help engineers who have to purchase them by giving a better understanding of the subject.